Cain (Wm)

NORTH CAROLINA BOARD OF HEALTH.

Sanitary Engineering.

SECOND EDITION.

By WILLIAM CAIN, C. E.
Member of the North Carolina Board of Health.

RALEIGH:
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CHAPTER I.

GENERAL CONSIDERATIONS.

Death rates lowered by sanitary works.—We are told upon the best authority that in England there occurs annually upwards of four million cases of preventable sickness; and that 125,000 persons are premature cut off every year from a neglect of sanitary precautions.

Now if this be true in a country which has adopted the best known sanitary precautions, at great expense, how much more significant will the records in this State appear, where the only outlay that may be classed under the head "sanitary," is generally made in meeting *doctors' bills* and *funeral expenses.*

It is further stated that in England, since the sanitary precautions have been instituted, that the death rate has been lowered by from one-fourth to one-third, and is besides decreasing from year to year. The following table, referring to a *few* localities in England, taken from Latham's "Sanitary Engineering," speaks more forcibly than all the other arguments that may be presented, especially to those who have paid but little attention to sanitary subjects, and are inclined to be skeptical as to the great actual saving of life that may be attained. I presume the table is made out

for 1873, the date of the publication, and that the "works" are of the "water sewerage" kind:

Name of Place.	Population in 1861.	Average mortality per 1,000 before con'tion of works.	Average mortality per 1,000 since comple'n of works.	Saving of life. Per cent.	Reduction of typhoid fever. Rate per cent.	Reduction in rate of phtyisis. Per cent.
Banbury,....	10.238	23.4	20.5	12½	48	41
Cardiff,......	32,954	33.2	22.6	32	40	17
Corydon,...........	30,229	23 7	18.6	22	63	17
Dover,........	23.108	22.6	20.9	7	36	20
Ely,.....	7,847	23.9	20.5	14	56	47
Leicester,..........	68,056	26.4	25.2	4½	48	32
Macclesfield,......	27,475	29.8	23.7	20	48	31
Merthyr,.....	52,778	33.2	26.2	18	60	11
Newport,..........	24,756	31.8	21.6	32	36	32
Kugby,..............	7,818	19.1	18.6	2½	10	43
Salisbury, ...	9.030	27.5	21 9	20	75	49
Warwick, ...	10,570	22.7	21	7½	52	19

A previous statement would indicate that the death rate is still being steadily lowered. As Latham states, the most healthy districts show but a small saving compared with the others; though nearly all show a marked diminution in certain diseases—typhoid fever and phthisis.

Similar results have attended the enforcement of sanitary measures in some of our American cities.

A striking illustration is St. Louis, where, it is stated, that from 1867 (when the Board of Health was organized,) to 1877, although the population had more than doubled, the death rate had decreased, so that actually in 1877 there were fewer deaths than in 1867.

The average mortality for this country is about 20, ranging from 17 to 30 in 1,000 generally; but St. Louis shows a death rate of only 11, which apart from its site, "must be ascribed largely to its excellent water supply and sewer system."

Economical Aspects.—Apart from the humanitarian view of this question, it may be considered in its economi-

cal aspects: thus Latham has taken Croyden, where the total cost of sewers, &c., was $943,800, and estimated the saving in *funerals*, in *sickness* (allowing that for every life saved 25 would escape sickness, the saving being estimated at $5 for every sick person,) and in the *labor*, for 6½ years only, by the prevention of premature death, at a total of over $1,000,000, which thus exceeds, in the short space of 6½ years, the total cost of the sanitary works.

Yellow Fever caused by Filth.—How much more striking would be the result, were we to take some of our own plague stricken cities in America! *Where has the yellow fever its origin?* In the filthiest port in the world, Havana, where "the tide being almost imperceptible, all the emptyings of the sewers remain in the harbor until they become a fœtid and revolting mass of corruption." From there the seeds of the yellow fever are carried by ships to other ports; and when these are foul, the scourge begins.

Gen. Butler at least has the merit of having to a great extent kept New Orleans clean and free from the epidemic during his occupancy of the city. In 1878, however, in consequence of the foulness of the city, she suffered the most terrible visitation; whilst in 1879, through the energetic workings of some of her most public spirited citizens, in carrying out sanitary measures, the mortality from yellow fever was very much reduced.

Galveston was kept clean and escaped the plague. Huntsville, Ala., actually sheltered yellow fever victims with impunity; whilst Memphis in 1879 again suffered from her foulness.

What more instructive lesson than the facts just given?

Advantages of Keeping Clean.—If we keep clean there is less chance of dying, greater enjoyment of life from increased health, fewer bereavements and a positive pecuniary gain to the community, even including the cost of sanitary works. Health, population, and money values also, generally go hand in hand, when other conditions are avorble.

On the contrary, if we disobey the Divine Will, by running counter to natural laws, we are punished for the sin of disobedience. Here we have rewards and punishments—both teaching their own moral lessons. Choose between them.

Is North Carolina Clean?—Let us now inquire as to our own cleanliness, which, the good book tells us, is next to Godliness. The result of this inquiry would be, that typhoid fevers, diphtheria and certain enteric fevers *that are now classed as "filth diseases,"* are common, especially in the larger towns of the State; and that these diseases are sufficiently accounted for by *bad wells, foul yards, privies,* and *cess-pools;* the latter tainting the air with their gases and the water with their dissolved impurities.

There are but few privies in the State that ought not to be abolished, and some good system substituted in their place. It is one object of this paper to suggest such systems.

But it is not sufficient that our own house alone be free from reproach. The individual may suffer when it is only his neighbors who are to blame. The whole community, as a unit, must practice cleanliness.

The germ of disease, engendered amid the surroundings of filth, if wafted to the palace, can strike as deadly a blow there as in the dirty hovel, as recent examples show.

Filth and Disease go hand in hand.—Of the exact nature of the poison generated by filth we know little; but it has certainly been demonstrated in numerous cases that the ravages of epidemics are in direct proportion to the foulness of the locality. Thus in one city, diphtheria followed the line of bad sewers, in another of bad wells. Bad water is one of the most efficient agents in spreading disease.

The cholera of 1853, in London, attacked districts furnished with unfiltered Thames water with 3½ times the severity experienced by neighboring districts supplied with Thames water filtered through sand and charcoal.

It has become, as it were an accepted truth in sanitary science that the fatal effects of epidemics may either be prevented, or their spread materially hindered by a proper attention to sanitary precautions. These precautions simply consist in the having, at all times, *pure air*, *wholesome food*, and *good water*. It is only the first and last of these requisites that will be considered in what follows, as they pertain more especially to the science of "Sanitary Engineering;" though it is to be observed that wholesome food is to to a certain extent dependent upon the good water or milk used in the cooking.

By a disregard of these prerequisites to health—and they are more or less disregarded by us all—we enfeeble the system, suffer a loss of vital energy, and are thus fit subjects for an attack by the first epidemic.

The "debilitating effects" of large cities are mainly due to the poisonous gases, generated by the putrid matter of sinks, sewers, &c., which gases find their way into chambers through faulty pipes and traps, or are otherwise diffused through the atmosphere. When the debilitated person seeks the pure water and bracing air of the mountains, the relief is almost instantaneous, thus proving the life-giving qualities of pure air and pure water.

The Science of Prevention.—The Science of Medicine, so long confined to the art of healing alone, now declares in favor of the *Science of Prevention* as the higher philosophy.

Let us, then, state the principles of this latter science clearly and succinctly; not entering into many details, but giving mainly those principles and facts that should be known by every one. Any system proposed must be a simple one—the simplest is generally the best—to meet the needs and comprehension of all classes.

The law organizing the N. C. Board of Health requires a monthly report from each county on vital statistics. It is of great importance that this law be faithfully carried out,

so that the effect of the suggestions given below, where carried out, may be ascertained.

The same act requires that the Board "shall gather information, for distribution among the people, with the especial purpose of informing them about preventable diseases."

Disease may be prevented, other conditions being favorable, by a proper attention to *drainage, ventilation, water supply,* and the prompt disposition of *sewage matters.*

We shall consider the subject in the above order.

CHAPTER II.

DRAINAGE.

Wet and Dry Soils.—The farmer well knows that when a wet soil is not drained, valuable plants refuse to grow, due to the land being "cold" and "sour;" and that by drainage such lands are often converted into the best quality of lands, owing to the replacement of the excess of water and vegetable acids by warm, dry air, so that the roots now find the proper amount of air, moisture and temperature to satisfy the conditions of growth.

The sun's rays now cause a *healthy* decomposition of organic substances, in place of the imperfect one that seems the necessary concomitant of moisture in excess; so that now neither acids are formed in the ground, nor dangerous organic impurities thrown off into the air.

It is the latter that produce, indirectly or otherwise, the *intermittent and remittent fevers*, so common over the whole South. The best cure is *drainage.*

"The fens of Lincolnshire, in England, and marshy districts along the lower Thames were formerly greatly scourged with fever and ague and with malarial neuralgia. The extensive drainage operations carried on in these districts have had the effect of removing these ailments entirely."

Where ground is water-logged, it is unfit for human habitation.

Drainage is especially necessary where sewers are laid, as the sewer gases readily penetrate the brick walls of the sewers, and then find access to cellars, etc. A dry soil will condense enough oxygen to burn these gases up, as will be more fully explained further on.

Malarial Poison.—It is generally believed that all damp places, as most ponds, marshes, swamps, river bottoms subject to overflow, etc., *portions of which, along the banks, are*

alternately wet and dry, are such as originate malarial poison, and must continue to originate it so long as such conditions hold. The occasional overflow of salt water aggravates the evil, as also the accumulation of leaves, decaying wood, etc., especially where thick vegetation causes a stagnation of the air, with dense shade. It is obviously correct then to cut down such vegetation immediately around the damp locality, drain it and put it under cultivation. If the rise and fall of the water, in the pond or marsh, alternately covers and exposes much of the banks—*i. e.*, if the banks are not vertical, or made so—then the body of water must be entirely drained off, if possible; otherwise the injurious decompositions due to wet soils will continue to go on and breed malaria. It is found that winds can transport malaria some miles. It is therefore best not to cut down open forests at a little distance from the damp localities, as they intercept the malaria to a considerable extent.

It is very often the case that dwelling houses, in city and country both, are surrounded with such a dense mass of shrubbery (perhaps intended to satisfy the æsthetic taste) as to cut off both fresh air and sunshine; thus rendering the house and yard damp and the air impure. Such vaults should be rendered habitable by the free use of the axe. It is not well to have too much shade in our cities; pure air and sunshine are the best purifying agents we have. It is a custom (but rarely "honored in the breach") to deny earnestly and with many asseverations that malaria affects the locality one lives in. Sad must be the condition of that person, who, even if he admits an occasional malarial fever, cannot point out another locality where the malady is infinitely more distressing.

Acting upon this recognized principle, it is suggested that whilst the mountains and hilly regions hardly ever originate fever and ague, that much of the remainder of the State is subject to it to a greater or less extent, and therefore that thorough drainage is one of the first requisites to increased

healthfulness. Whilst thinly settled districts may not be able to institute proper precautions, yet the larger towns can drain the ponds, low places, roads and mother earth generally in their vicinity.

In the last column of the previous table is seen the reduction in the death-rate from phthisis of twelve English towns. "This saving of life is ascribed to the effect of drainage works in drying the subsoil of those places."

In this State, Salisbury may be given as an instance where the drainage of a large pond near the town has very largely diminished the prevalence of malarial fevers.

Subsoil Drainage.—In the subsoil drainage of streets and roads, *covered drains*, formed of rock or tile, should be used in preference to open drains. Open drains, unless the soil is very tenacious, and can stand at a steep slope, take up too much space. Besides they are constantly needing repairs and often hold stagnant water and decayed filth ; so that in some countries their courses have been marked by excessive ravages of cholera over adjoining districts.

A given tract of land is best drained for agricultural purposes by stone or pipe drains of 1 to 2 inches diameter, running straight down the hillsides (when not too steep), in parallel rows, 25 to 50 feet apart, and 30 to 36 inches below the surface. These small drains discharge into larger intercepting drains, run down the hollows ; and these, in turn, empty into larger drains (that may often be open), that follow the courses of the valleys and perhaps serve as the water channels of small streams. Such draining necessarily ensures a deep, mellow soil, that not only satisfies the needs of agriculture, but is in perfect keeping with the requirements of health. Towns should at least keep the subsoil dry, by covered drains run along the streets and elsewhere, at sufficient depths to drain the cellars thoroughly and to prevent standing pools of water.

Tile drains 2 inches in diameter, under the side-ditches, or one 3-inch drain under the middle of the road, is suf-

ficient generally. An outlet drain should run from the depressions in the road. A drain or culvert crossing the road should be large enough to pass 2 inches of rainfall in one hour when the drainage area is small, 1 inch for a valley two to three miles long, and so on.

All streets and roads should be built higher in the middle than at the sides, and should have gutters deep enough to carry off storm waters, unless there are specially constructed large drains for this purpose (as to which see "Water Sewerage," further on).

Complete Drainage.—If such drains (designed to carry off *all* the rain water, slops and waste water that is not absorbed by the ground,) are contemplated, regard must be paid, in laying them, to the future sewerage of the town, even if this is not carried on at the same time as the drainage system proper.

The drainage of large districts, swamp lands, low lands, etc., varies so with the configuration of the ground that it is impossible to give any set of rules that apply in all cases. As a rule, the district is intersected by a number of dykes, often parallel, that drain into larger dykes or streams.

Intercepting dykes are often dug around the whole area to be drained to prevent the access of water from without.

As an illustration, the low "Landes" in France may be given. Here 260,000 acres of the richest lands in France have been reclaimed, chiefly by cutting open canals 16 to 20 feet wide, following the natural slope of the plateau with a fall of 1 to 2 per 1,000. Of these canals 1,600 miles have been completed. For 75 miles along the coast, huge sandbanks protect the country from the sea, the drainage along them being received by a large collecting canal 40 feet wide. The works cost $1,700,000, about; and the value of the reclaimed land is estimated at upwards of $56,000,000.

"*The fevers which formerly ravaged the country have disappeared, and the country may now be considered one of the most healthy in France.*"

If the land is beneath the sea level, as in Holland, then the water must be pumped out of the area, the latter being protected from the encroachments of the sea by an embankment.

Straightening the course of rivers, likewise, is efficient in causing increased scour, a lowering of the bed and a lessened liability to overflow.

Ponds are easily drained by simply cutting a ditch of the proper size through the natural or artificial embankment surrounding them. The greater the extent of the water shed, and the greater the rainfall, and the imperviousness of the surface, the larger of course is the ditch.

The so called "wet weather" ponds, often on high ground, should never be tolerated, as they present the very conditions for fostering malaria—a large area, alternately wet and dry.*

The natural division of a country for drainage purposes is into districts belonging to the same water shed, bounded, of course, by the ridges and streams. Considerable inconvenience has been caused in some thickly settled countries by a disregard of natural boundaries.

The extent to which drains exert an influence on the ground on either side depends on their depth, and the character of the soil, whether very retentive or porous. Their action is analagous to that of wells given further on, except that the bottom of the ditch does not generally reach the level of complete saturation of the ground as is often the case in wells.

It is best not to open new ditches from "June to November" in malarial districts, unless for house drainage. Cellars should be drained by leading a pipe from below the bottom of the cellar to some convenient exit to the open air

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*See Kerr's Geology of N. C., (Introduction) for an excellent presentation of the leading topographical features of the State, especially its swamps and pocosins, as relating to the matter in hand.

at a lower level; or similar drains may be laid just outside of the building.

It is plain that greater attention should be paid to drainage in towns near our sea coast than in the hilly regions, as decomposition is generally greater, due to increased moisture and temperature, not forgetting however that its neglect anywhere must cause pernicious effects.

CHAPTER III.

VENTILATION.

The Constituents of the Air.—It has been found that in certain manufactories and machine shops that the air is so filled with certain impurites that 30 years is the maximum age attained by the operatives. Such instances (and they may be multiplied), though they indicate criminal neglect in the management, are fortunately exceptional, and need not be considered here.

The impurities that we shall consider under this head, as concerning ventilation, result from the *breathing of men and animals and the burning of gas, oil, etc.*, in illumination and heating.

Country air, wherever analyzed, is found to contain in volume nearly 1-5 *oxygen* to 4-5 *nitrogen*, with small variable amounts of aqueous vapor, ammonia, carbonic acid and certain microscopic organisms, besides dust, etc.

If phosphorus is burnt in a bell jar, placed over water, it combines with nearly all of the oxygen in the confined air, forming white fumes of "phosphorus pentoxide," that are soon entirely absorbed by the water, leaving nearly pure nitrogen in the jar. The water rises so as to fill about one-fifth of the original air space in the bell jar, thus showing that the substance (oxygen) abstracted is nearly one-fifth by volume of the whole. The gas (nitrogen) now remaining in the jar is colorless, inodorous, and does not support combustion or animal life. Pure oxygen gas, (which is readily obtained separately by heating mercury oxide or potassium chlorate, etc.), is likewise colorless and inodorous, but it supports combustion readily—iron even burning (oxidizing) in it with great brilliancy.

The oxygen is the life-giving principle of the air. An animal, however, exposed to pure oxygen gas is over-stimulated to such an extent that it soon dies. The nitrogen, therefore,

acts as a diluent of the oxygen, and it is found that the above proportion of 4 to 1 cannot be much varied from without deleterious consequences ensuing. The oxygen is not *chemically* combined with the nitrogen, it is simply mixed with it as sugar is dissolved in water—the little atoms of the one penetrating the spaces between the atoms of the other without destroying the transparency of the medium.

Dr. Angus Smith has made a large number of analyses of air in various parts of Great Britain. The amount of oxygen by volume in 10,000 parts of air are given for various localities as follows:

Mountain air,	2099 parts.
Towns (average),	2096 "
Room (rather close),	2089 "
Pit of a theatre, 11.30 P. M.,	2074 "
Backs of houses and closets,	2070 "

When air contains only 1850 parts of oxygen to 10,000 of air, it will not support the combustion of a candle, neither will it support life long. The relative densities of oxygen and nitrogen are as 16 to 14, so that an average composition of air by weight in 10,000 parts is oxygen 2310, nitrogen 7690.

The invisible *aqueous vapor* exists in the air at all times in various quantities, often condensed as visible clouds, dew, etc. Its amount varies greatly with the temperature. Thus one cubic foot of air at 90° Fah. can hold 14.50 grains of aqueous vapor as invisible gas; whilst air at the freezing point, 32° Fah., can hold only 2.37 grains of water gas. The air in both cases is said to be "saturated," since it cannot hold any more water gas, as gas; any excess being precipitated as rain, or formed into the liquid particles constituting fog or cloud and becoming therefore visible. In fact suppose air, saturated at 90°, to be cooled down to 32° suddenly: then 12.13 grains of rain will fall for every cubic

foot of air, leaving only a little over one-seventh of the original moisture in the air! It is upon this principle that the phenomena of rain, dew, etc., depend.

It will have been noticed by those who read the daily reports given by the signal stations, that there is a column marked "relative humidity." This gives the per centage of full saturation of the air at the time of observation. Thus, "relative humidity 60," would indicative that the air contains 60 per cent. by weight of the water gas it can hold, without fog forming.

From Kerr's Geology of North Carolina, p. 87, we find the average yearly humidities of several places as follows: Wilmington 57, Charlotte 65, St. Louis 67, London 80 and New Orleans 86; the first two giving only the mean from a little over one years observations. Whilst in London fog is common, on the coast of the Red Sea a cloud never forms, the dryest air there during a simoom containing only one-fifteenth of the saturating quantity.

Now it is well known that excessive moisture is deleterious to weak throats, lungs, etc. As to the effect of extreme dryness, I am not informed, save that these-little-red hot-panting-cast iron-stoves produce a bad effect on the air, which is very much ameliorated by evaporating water in vessels placed over them. The bad effect must be due largely to the drying of the air. Thus to take our previous example, if the air near the stove is heated only from 32° to 90°, and we suppose it "saturated" at the lower tempera ure, then at the higher one it has only the same amount of water gas, but it can hold nearly seven times as much; and if we suppose it only half saturated at 32, then at 90 it will be nearly as dry as the air of a withering simoom, and at highest temperatures much dryer! Such extremes cannot fail to be unwholesome, and therefore if stoves are to be used, let them be *large* and heated as little as will give the necessary warmth.

Another important constituent of the air is *ammonia*, though it exists in comparatively minute quantities (about 1 in 1,000,000 of air); still it is mainly from this ammonia that vegetables obtain the nitrogen necessary to form their seeds and fruit. It is given off from urine and stable manure, unless gypsum is added to fix it. It is not injurious by itself in small quantities and need not be further considered.

The most important, by far, of the inorganic air constituents, next to oxygen, is *carbonic acid.* Its amount varies within wide limits; thus in Scotland, mountain air contained 3.2 at top of mountain, to 3.4 at bottom, in 10,000 volumes. In London it varies from 3 in open parks to 3.4 on the Thames, and 4 as a rough average, on the streets. In Manchester, the amount of 6.8 to 10,000 was reached during fogs, which is slightly over the extreme allowance considered advisable, which has been fixed by some at 6 in 10,000 volumes. Carbonic acid is formed by the chemical combination of carbon with oxygen. Thus when wood, coal, oil or gas is burnt, carbonic acid is formed. It is also given off by the decay of wood, in certain decompositions, and in the breathing of animals. In fact, if the air in a jar is extracted and then returned from the lungs into the jar again, it will not support the combustion of a candle, although the amount of carbonic acid expired is only 5 per cent. The lungs and body likewise exhale *organic impurities*, about in proportion to the amount of carbonic acid thrown off, the nose readily detecting the vitiation due to this cause. It is thought by many that these organic impurities—fatty matters thrown off from the skin, particles of skin, odors, etc., from man and beast—although constituting only the one hundred millionth part of air in the country, or about the five millionth part in crowded cars, is still the most dangerous to man of the air constituents; for it is in every stage of decomposition, and must furnish food for the microscopical denizens of the air, some of which no

doubt are scavengers, but others are thought by some to cause disease.

The Atmospheric Germs.—It is well known now that fermentation and certain chemical changes are brought about by minute vegetable or animal growths, whose natural habitat is the air. Tyndall has filtered air through cotton wool to put next the most decomposable substances, and found that no change occurred in them, whilst common air caused decomposition or fermentation to begin. These experiments pretty conclusively disprove the theory of "spontaneous generation." Whether epidemic diseases owe their origin to "atmospheric germs" is not certainly known as yet, but thet heory is at least plausible, and explains many facts more fully than any other theory generally known.

We know this much, that sewer gas, even in the minutest quantity, is sometimes fatal, (which is not due to the chemical gases formed, for the chemist breathes them every day), at other times innocuous, especially when free ventilation has been secured. Similarly the discharges, and even garments, of patients suffering with certain fevers can communicate the disease. Yellow fever, cholera, small pox, etc., is transported in ships by mere clothing. These facts, in connection with the fact that certain organisms in the air seem to follow cholera (as was shown in Germany, and the microscope may reveal the same thing in connection with other epidemics), seem to point to the atmospheric germ as being connected intimately with certain diseases. While the truth is being worked out by scientists, let us make use of known facts and proceed to "scotch the snake" wherever its presence may be reasonably suspected.

Vitiation of the Air by Breathing and Illumination.—It is found that a man gives off somewhat over 6-10 of a cubic foot of carbonic acid per hour; that a lamp or two lighted candles produce the same amount, and that a gas jet, burning 3 cubic feet of gas per hour, produces as

much carbonic acid per hour as two or three people. It is true that the gas gives off no organic impurities, but if not burning brightly the poisonous carbonic oxide is always formed.

If we adopt 6 volumes in 10,000 as the safe limit of the amount of carbonic acid to air, then it follows that for every man or lamp or two candles in a room, we must supply at least 1,000 cubic feet of pure air in every hour to dilute the $\frac{6}{10}$ cubic foot of carbonic acid formed. A gas jet will require two or three times as much pure air.

But since the admitted air contained carbonic acid, we must supply more air to not exceed the maximum adopted; thus if the admitted air contain three volumes in 10,000 of carbonic acid, we must admit 2,000 cubic feet for every person, since the 6-10 of carbonic acid admitted, added to the 6-10 expired per hour, gives the ratio of 12 to 20,000 or 6 to 10,000 allowed.

It is said by some, that experience in hospitals shows that from 2,000 to 3,000 cubic feet of fresh air should be admitted every hour for each individual; whilst again we are told that for a healthy person in a barrack room 1,200 cubic feet per hour will suffice, and that the vitiation, tested by the sense of smell, for hospitals is not perceptible when somewhat less than the 2,000 to 3,000 cubic feet are provided.

No fixed standard has thus been agreed upon. In fact, it doubtless varies with the climate and the health of the person. The Laplander can breathe impure air better than we, probably because the organic impurities thrown off by him are not so readily decomposed as in our warmer air. The carbonic acid formed by combustion and respiration being heavier than air at the same temperature, would sink to the floor; but in consequence of its high temperature, it first rises to the ceiling; so that as much as 60 to 70 parts of it in 10,000 of air has been found at the top of an ordinary sized room in which two people were sitting and three gas

jets burning. *At the same temperature*, however, we should expect to find the largest amount of it at low elevations, thus vitiating the lower strata of the atmosphere, or room, very greatly. Fortunately, however, gases have the power of "diffusion," so that a heavy gas will actually rise to mix with a lighter gas: further, it will pass through membranes and thin plates of stucco to effect the same object, so that the amount of carbonic acid is not generally a function of the elevation of a locality.

Where a room has no flue or chimney to keep up a constant circulation, then openings should be provided near the top of the room to let the warmer impure gases out, and not let them cool and descend again to vitiate the air we breathe.

Vitiation by Perspiration.—In addition to the carbonic acid given off by the lungs and skin of a man, there is exhaled a considerable degree of moisture, generally loaded too with organic matter, which produces smell. The amount has been estimated at from 1.5 pounds to 2.5 pounds per day on an average. A high temperature, or exercise, causes greater perspiration, thus cooling the person somewhat.

The amount of moisture given off is considered by some in connection with the carbonic acid exhaled, to ascertain the theoretical amount of air to admit; but this theoretical amount for most houses is larger than healthy persons seem to require, according to certain experience. This is accounted for by the fact that opening doors and windows, especially if they are kept open for some time, the draft through cracks, &c., add very much to the volume of admitted air, though not considered in the computation.

Lime as a Purifier.—If a house has been lately plastered or white-washed, the lime will, at first, take up the carbonic acid with avidity; so will any ordinary mortar; in fact, I have seen artificial stone made by passing the products of combustion of a stove (carbonic acid mainly) by a flue into a room where was placed the mortar, moulded into the re-

quired form. The lime of the mortar changed to carbonate of lime, which cemented firmly the grains of sand into a hard rock.

It destroys organisms to whitewash. It would seem, therefore, that a plastered wall whitewashed was better than either the "hard finish" or papering. The accumulation of filth in successive coats of papering in old houses is probably frightful. Most of us have seen the trunks of trees whitewashed. This seems to me a misdirected effort to promote health. Why should such indignity be practiced on our noblest growths, stopping up the pores of the bark and probably injuring the tree, in order to remove a little carbonic acid *out of doors,* where it is not in excess?

The Leaves of Plants as Purifiers.—The carbonic acid thrown off into the air by decomposition, lighting, heating and the breathing of animals, is taken up by the leaves of growing plants, where it is decomposed, by aid of the sun's rays; the carbon being appropriated to help make woody fibre, &c., and the oxygen being given back to the air to fit it for respiration. We cannot imitate this process in ventilation schemes, but have to resort to heated currents or to fans to expel the foul air from our rooms and leave it to nature to carry the foul air by the winds to her millions of laboratories and return it to us pure. If there was *no* vegetable growth, however, it has been computed that the breathing of animals would not vitiate the air perceptibly, over the whole globe, in some thousands of years.

Limit to Ventilation Schemes.—It is impossible to change the air, *with comfort,* in a room, as often as the winds do, out of doors; but we can easily prevent the air in the rooms from becoming too impure to breathe. Even when there is no special attention paid to ventilation, it is found that the hotter inside air is going out continually, through every possible outlet, and cool fresh air coming in to take its place. In very open houses, ventilation is often secured

by the poor construction, in spite of the inmates, but it is often at the sacrifice of comfort.

Ventilation by the Open Fire-place.—Let us now consider one method of supplying pure air to a room containing an open fire-place. A fire must be kept brightly burning in the fire-place, to heat the air in the chimney or flue, causing a difference of pressure in the external and internal air, so that the out-door air rushes in through every crack and crevice, even through the solid walls, and thus forces the foul air up the chimney.

It is found, however, by experience, that the openings mentioned are not generally sufficient to admit a sufficient volume of pure air. Hence our custom is, at intervals, when headaches or debility are experienced, to open the doors or windows "to let in a little fresh air." A wise precaution certainly; but it does not meet the whole case, for *air should be admitted without draft—i. e.*, without the influx of sharply defined cold currents, which, as is well known, produce colds, with their attendant evils. The problem has been solved, however, in several ways, the details of which are simple in the extreme.

Thus, if the lower sash of the window is raised a few inches and the opening below it is completely closed by a strip of plank, there will still remain an opening between the sashes where they overlap, through which the air will pour, being necessarily directed upwards. It thus strikes the ceiling, and is then gradually diffused through the room without draft.

A common expedient of simply lowering the top sash allows the cold air to "trickle down" on our heads. In the latter case, however, a board may be placed at an inclination against the upper part of the sash, so as to give the entering current an upward direction.

Either of these plans is liable to failure when curtains or blinds are used. So that a more generally applicable method would consist in boring holes through the upper

part of the doors or walls, and giving the entering air an upward direction by means of inclined planes of some kind; or tubes of wood or iron may be passed through the walls and turned directly upwards on entering. They should extend to at least 7 feet above the floor.

The air in all cases should be drawn directly from outdoors, and not from passages or other rooms. The openings, moreover, should admit of being partially or entirely closed on very stormy and windy days. All of the above plans have been tried in dwellings, club rooms, etc., with complete success.

The proper size of tube or opening to use must be determined by experience. Two tubes, of two inches diameter each, may be tried for an average-sized room for two persons. It is stated that "two square tubes, 5x5 inches, will keep a good-sized club-room *fresh*."

Now, this method of ventilation is dependent upon a fire being maintained at the lower level of the room to cause the currents to enter with sufficient velocity. The system fails in summer; when, however, we do not object to the draft caused by opening the doors and windows.

Known Properties of Air.—The mathematics of this branch of the subject, (which is not given, as it seems out of place here,) depends upon certain known properties of air which may be briefly mentioned. Thus 12.4 cubic feet of air weighs 1 pound, when at a temperature of 32° F, the barometric height being about 30 inches, the average pressure at the sea level.

Since air is compressible, (its volume varying inversely as the pressure,) it follows that as we ascend, the weight of the same volume of air becomes less, since there is less air above us than before, so that the same weight of air is not compressed into so small a place.

Air likewise expands or contracts 1-491 part of its volume for each degree Fahrenheit above or below the frezing point, the pressure remaining the same; so that 491 volumes of

air at 32° becomes 499 volumes at 40°, 509 at 50°, 519 at 60°, 529 at 70°, 539 at 80°, and 549 volumes at 90°, whilst the 491 volumes at 32° F. become 479 at 20°, 469 at 10°, and 459 at 0° Fahrenheit.

Again, it is found that one pound of air can be raised 1° F. by the same amount of heat that will raise 0.2374 lbs. of water through one degree, the air being subjected to constant pressure.

From such data, in connection with the heat afforded by different fuels, and the laws affecting the flow of gases, we are enabled to compute the velocity of the air flowing out of the chimney, which is thus a measure of the inflow of the fresh air. Suffice it to say that the higher the chimney or flue the stronger the draught, as thereby the difference of weights of the heated air in the chimney and a similar column outside the chimney is greater.

Ventilation by Gas Jets.—In theatres and closed halls, a series of gas jets may be used to create a current, the heated air passing outdoors through flues placed directly over the gas jets.

It is stated that this plan has met with great success in two churches in New York, the size of one of them (Dr. Scudder's church) being 150x100, of the other (Dr. Hepworth's) 125x125; the first seating 2,200 and the second 2,400. There were 14 to 20, 12 inch round tin pipes, carried up in walls from near the floor to and above the roof. In each of these tubes was placed three gas burners, just above the registers that admit air from the outside. On simply heating some of these gas jets, the registers being opened the proper amount, there is caused a quick exhaust, under complete control, and an inflow of pure fresh air. There is an opening in the centre of the ceiling of the auditorium into an octagon shaped shaft 11 feet in diameter in one church, 16 in the other, extending above roof, containing sashes and outlets to the outer air. Gas jets are placed under tubes in these shafts to increase the current. At other parts of the ceiling are similar shafts, etc. The nu-

merous gas jets produce such a current that, *in warm weather*, the entire air of the church can be changed every five minutes. The churches are heated by hot air furnaces or steam coils. (See "Plumber and Sanitary Engineer," March, 1879.)

Ventilation by Fans.—Still another method of ventilation is by pumps and fans. Most generally, air is drawn from without by fans located in the basement, and is propelled along ducts—over steam pipes or furnaces, if it is to be heated—to openings into the various halls and rooms, from whence it escapes by suitable openings, generally placed in the roof. The air is often drawn from near the ground, but it is best, especially in densely populated cities, to draw the fresh air from a point 100 to 200 feet above the ground down vertical shafts. In Paris, the air is drawn down a shaft 180 feet in height, to supply the Assembly room. (See Appendix III for a description of the ventilation of the N. Y. Lunatic Asylum.)

Good Effects of Ventilation.—It is evident how important a factor of health ventilation is in crowded school rooms; in fact in all places where crowds may congregate and speedly vitiate the air. The bad effects are everywhere admitted. The good effects of the systems proposed have been proved by mortuary statistics, especially in school houses and hospitals. In a Dublin hospital, in 1783, for 25 years when the ventilation was bad, 3,000 out of 18,000 children, born there, died within the first fortnight of their birth. With better ventilation in the succeeding 28 years, 550 died out of every 15,072.

The report of 1861 states that further improvements in ventilation have been made, and deaths from the "nine-day fits," which carried off most of the infants, was then almost unknown.

The records concerning ventilation in connection with lung diseases is equally striking. Such diseases thrive in cities where the smoke resulting from the burning of *coal*

is charged with impurities, such as "hydrocarbons, sulphide of ammonium, carbonic oxide, and probably very minute quantities of arsenic." Even now the cry is going up from London for a purification of its atmosphere from smoke. This evil we do not suffer much from in North Carolina, the population being scattered and the cities small. But we need a thorough inspection of public buildings with a view to proper ventilation.

When it is known that 30 parts of carbonic acid to 10,000 of air is often found in theatres and public halls, which is five times the admissible amount, it will be admitted that reform is needed.

Cubic Space Allowed.—*The amount of space per head allowed in the room by various authorities, varies from* 300 *to* 1,000 *cubic feet*, the amount being smaller when the room is only occasionally filled with its maximum number.

It is true that the air can be changed in a small room more frequently than in a large one to maintain the proper degree of purity or rather impurity, but the increased draught may be objectionable. The amount of space *actually given* per head in various *school houses* varies from 70 to 100 to 200 cubic feet. The effect is that 12 parts of carbonic acid in 10,000 (double the admissible amount) is common, and even 20 and 50 parts are not unknown. The effect upon both teacher and pupils is of course, headaches, listlessness and debility.

Lighting.—The proper lighting of school rooms is as necessary as ventilation. The light should come from *behind* the pupil on to the book or blackboard, when possible, and the windows should be *high*, as most of the available light comes from above the level of our heads. Lighting directly from the top is probably the most efficient means of all where practicable. The light should come mainly from one side—the side opposite the blackboards—and the pupils should sit with their backs to it. The desks should be at such heights that the book or paper, &c., shall not be

too near the eyes, so that the tendency to near-sightedness may be prevented. This defect is becoming alarmingly prevalent, and the teacher should insist upon the pupil reading with the book at the proper distance to suit his vision, at all times.

Useful Hints.—Finally, let it be impressed upon all that the sense of smell when coming from outdoors into a room should warn us when our rooms are foul, and that doors and windows should be opened when convenient, and articles of clothing and bedding should be aired frequently to purify them.

Also let it be remembered that even brick walls can transmit gases. "Pettenkofer got 2,650 to 3,320 cubit feet of air through the brick walls and crannies of his room, when the difference of temperature inside and outside was 34° F. When all the crannies had been carefully stopped up, 1,000 cubic feet per hour still came through the walls." Therefore never allow filth about any room or cellar of the house, nor against the outside walls, for such filth will contaminate the air that comes into the room, and *has been found* to cause sickness. If the house is liable to such contagion from adjoining buildings, endeavor to make it as air tight as possible, after providing for the admittance of the purest air that can be obtained through proper openings. The floors of all houses should be as tight as possible.

Heating.—Intimately connected with ventilation is heating; in fact the two have generally to be considered together. In cold weather we require more heat than our bodies generate to make up for the loss by radiation; at the same time we need fresh air to breathe.

How admirably are these two conditions realized around a good camp fire, on a still, cool night! The active worker has just enjoyed his hearty meal, as only a worker can, and with feet stretched to the fire—that heats him by direct radiation—and body well clad, inspires the cool, fresh air of the country that invigorates body and mind.

Cool air to breathe is as refreshing as cool water to drink, whilst air too warm may be compared with tepid water in its effects. This fact is universally admitted, and yet it has got to be the fashion, at the North especially, to heat houses by puffs of hot air from furnaces that would seem more properly in keeping with a drying house. Let us understand clearly the physical differences in the various methods of heating, and we can then form a more intelligent judgment as to the merits or demerits of each particular device.

THE OPEN FIRE heats solid bodies in front of it, by *direct radiation* of heat rays, which pass through the intervening air with scarcely any loss. Tyndall has shown that air, consisting simply of oxygen and nitrogen, intercepts but an extremely small number of heat rays passing through it. The aqueous vapour, found in all air, intercepts 80 to 100 times the heat that pure air does. Carbonic acid, perfumes, etc., increase the absorption of heat by air. The water gas in the atmosphere, although constituting only, say ½ per cent. of it, yet intercepts nearly all the heat rays of the sun that do not reach the earth; and again prevents their too rapid radiation at night from the earth. As Tyndall says, "Aqueous vapour is a blanket, more necessary to the vegetable life of England than clothing is to man." The amount of heat, however, intercepted by the air between the fire of a room and solid objects in front of it, although small, yet *does* increase the temperature of the air somewhat, though it is usually neglected altogether. The air of the room is mainly warmed by "*convection*," from coming in contact with the solid objects that have a higher temperature; the air next the solid body being heated first, then rises, to be replaced by other air, which operation is repeated indefinitely, or until the whole mass is heated to the same temperature.

There is thus a continual circulation of the air in a room heated by an open fire place, and generally an efficient draught to keep the air from being too much fouled.

If the room is heated by STEAM OR HOT-WATER PIPES, the case is different. The direct radiation is small, as any one can test by trying to warm his feet at the pipes without actual contact. The warming is mainly effected, as in the case of STOVES (not over-heated) or HOT-AIR FURNACES, by the air being warmed, by the heated pipes, stoves or furnaces, by convection, and this air by its circulation heats the room and its occupants. The air is thus warmer than the furniture in the room; whereas in heating by the open fire-place, the furniture, etc., is often warmer than the air. A person in the room would thus be continually radiating heat, unless the air was too warm for comfort. In addition to the objection to the warm air, *per se*, it has been previously explained that heating air causes it to become too *dry;* so that whilst the "relative humidity" out of doors may be 80, in doors it may be much less—a disproportion that cannot be conducive to health. In fact, as a writer humorously remarks, such drying houses "are drying the very flesh off the bones of the Americans."

Still, in large buildings it is generally impracticable to heat by direct radiation, and the inmates have to submit to be dried. Again it is stated that the rigor of the Northern climate requires that the air, even in dwelling-houses, be heated somewhat before being admitted, If so, then it is still practicable to heat it only to 50° or 70° F., and supplement with the open fire-place.

Summary of Modes of Heating in the Order of Merit. —We shall conclude this popular exposition of the subject by a condensed summary of the various modes of heating in vogue, in the same order of merit as that given by Prof. Fleming Jenkin, in "Healthy Houses" (Harper's Half Hour Series), a book that every one should have.

The open fire-place is best, although most expensive, as it heats by *radiation*, and secures ventilation.

Next follow, in the order of descending merit, hot water pipes, porcelain stoves, hot air pipes, cast iron stoves, and

last and worst gas-stoves with no chimney. These pipes and stoves heat largely by *convection—i. e.*, by heating the air next to them, which rises and is diffused through the room, the cold air taking its place to be in turn heated, &c.

Iron stoves, especially when over-heated, emit a bad smell, supposed to arise from the charring or decomposition of organic substances in the air by their contact with the heated sides of the stove and pipe. Moreover, if the stove is red hot, the poisonous carbonic oxide and other gases will pass through the red hot iron and thus enter the room. The air is charred and dried too much by iron stoves. The porcelain are far preferable. Hot air pipes are better, and moreover distribute the heat more uniformly; though if the furnace becomes red hot, poisonous carbonic oxide will pass into the pipes. Some describe the "hot air" as having the "life taken out of it." Hot water pipes are better than hot air pipes; the air is not over-heated, and a uniform temperature is preserved for a long time. It is much used in hot-houses, baths, drying-rooms, etc.

Exits must be provided for the foul air where the hot-air system, the water pipes or the gas-stoves are used. For comfort and cheerfulness, no device can equal the open fireplace, fed with coal, or oak and hickory wood, not ignoring either the historic pine.

The fresh air then comes in through the walls, tubes, etc., *cold*, with plenty of oxygen and perhaps ozone in it, and is gradually diffused through the room as it becomes heated, to give up the proper amount of oxygen required for respiration and combustion. What excuse can there be for close rooms, that breed debility of various kinds, when pure, fresh air can be obtained by us at such a small cost?

CHAPTER IV.

WATER SUPPLY.

All of our supplies of water are derived from rainfall, part of this rainfall evaporating again, part running off into the streams and thence into the ocean to be again distilled and sent back to us as clouds and rain, and part sinking into the earth and forming the small subterranean streams which furnish the water of our springs and wells. In running over or through the ground, this water takes up such salts as it meets that are soluble. Some of these, together with the air and carbonic acid dissolved, giving the pleasant taste to our usual potable waters.

Other salts and gases, derived from decaying organic matter—dead bodies, manure, filth, etc.—are harmful in the highest degree, and have bred mischief and death in innumerable cases.

The rain as it leaves the clouds is pure water generally; but in falling to the ground, it not only carries with it mechanically much organic matter and dust that is floating in the air, but it dissolves various gases, as oxygen, nitrogen, carbonic acid and ammonia (the usual constituents of the atmosphere) besides nitric acid (often formed in the air by the lightning's flash), and in the vicinity of manufacturing towns, the gases evolved in the processes used in the particular manufacture. Water readily dissolves certain gases. On simply shaking it up with air, the latter is readily dissolved. This principle is made use of in aerating the pure water, that has been distilled from the salt water of the ocean, on board ships, thus making it drinkable.

The amount of oxygen, nitrogen, carbonic acid and ammonia commonly found in waters is small, particularly the ammonia; which last, it may be observed, water can dis-

solve in large quantities. All of these gases are easily expelled by simply boiling the water.

Rain water generally contains far less organic matter than river water. River waters, though, differ greatly in the amount and character of the matter, in solution and suspension, as regards potability. Thus, if water drains over an impervious stratum, as a granitic formation, the water is apt to be soft, and to contain but little solid matter in solution. Some waters of this character contain only from three to five grains of solid matter to the gallon; they possess a high solvent power on lead and iron pipes, but are otherwise of the best character.

Where the rocks consist largely of carbonates of lime or magnesia, the waters are apt to be hard, their action on lead and iron pipes is small, and they require a greater expendi, ture of soap in washing, but are not otherwise objectionable, unless the carbonates are greatly in excess.

It is stated that the health and physique of hard water districts is better than in soft water districts; the water furnishing an abundance of material needed in the formation of the bones.

Each "*degree of hardness*" (*i. e.*, each grain of chalk or sulphate of lime, dissolved in a gallon of water) will entail, however, the additional use of two-and-a-half ounces of soap for every 100 gallons of water; so that it is well to get rid of the carbonates in solution, if possible. This may be partially effected in two ways; either by boiling the water, or by adding milk of lime. Both methods depend on the fact that water can dissolve only two grains per gallon of carbonate of lime, unless it contains carbonic acid in solution, when it can dissolve very much more.

Boiling expels this acid; thus reducing the amount of carbonate of lime in the water in solution to, at most, two grains per gallon. By the second, called "Clarke's process," the added lime-water combines chemically with all the free carbonic acid, forming carbonate of lime, which thus settles

to the bottom, together with much of the original carbonate of lime, leaving only about two grains per gallon still in solution of carbonate of lime.

The milk of lime is made by shaking up a small quantity of quick lime in water.

Permanent hardness of water is caused by the presence of sulphates of lime and magnesia. Neither boiling nor Clarke's process can soften such water.

Wells and Springs.—Where *wells* or *springs* are used as the source of water supply, great care should be taken that the surface in their vicinity be kept free from organic matter, which by oxidation and putrefaction readily forms soluble nitrates, ammonia and chlorides.

Such waters are often clear, pleasant to the taste, sparkling from the excess of carbonic acid and cool from the effects of the nitrates. Hence the senses cannot be relied on, without the aid of a chemical and microscopical analysis to decide whether our well water is fit to drink. Even when all filth, slops, etc., are removed to a distance, we can only infer that there is *no probable* contamination.

The geological structure—stratification, faults, character of the earth, etc.—should be studied in this connection. Thus it was found in a certain locality that wells very near a grave yard gave good water, whereas wells on the opposite side, several hundred yards off, in the direction of the dip of the strata, were polluted to a dangerous extent. The explanation is simply that water has a tendency to flow along the planes of stratification, where the strata are well defined.

Numerous cases of fever, cholera, &c., have been traced to bad water; localities with wells situated on the subterranean current that flowed past the diseased refuse, cess pool, etc., being attacked, whilst neighboring localities were free from the epidemic. It is needless to specify particular instances. Let no wells be placed where kitchen refuse, slops, manure or any kind of fecal matter can drain into

them. Where no stratification exists, then, if possible, place the well two or three times its depth from any offending matter. A well can just as properly be dug next to the house as elsewhere, provided slops and kitchen refuse are emptied some distance from it. In one instance soapy water was found by analysis in one well, whose sparkling waters would never have suggested it. The whole of the slops of the establishment were thrown where they drained directly into the well.

It must be carefully borne in mind that the well is the point of least resistance to the numerous little streams entering it and that it may induce a flow from a considerable extent of the surrounding earth. Chemical analysis can alone show if some of these little streams have been polluted ; in fact, whether a well is the drainage receptacle of the filth on the surface or of the rotten cess pool—the disgrace of any land where it is found.

It is not intended to convey the idea that, before wells are dug, the underground water is necessarily flowing in little streams. On the contrary it is generally otherwise, particularly in very absorptive strata. Very hard rocks, of course, hold but little water, except in the crevices, whilst very porous and absorptive strata, as the London chalk, are fully *saturated* with water from near the surface downwards, and only need tapping to afford it in large quantities.

The water thus contained in the ground is known as the "soil" or "ground" water. Where the earth is porous, absorptive and uniform in character, much more of the rain water passes into the ground to flow off along subterranean channels to some outlet, to appear at the surface again as springs, or to be pumped out of wells—than where the surface is more impervious.

The imaginary line connecting the water level of springs and wells (when not used) is called "the line of saturation." It has been found that in uniform earth this line of saturation generally rises with the ground, so that generally as

we recede from the sea-coast, or a stream, the water level of the well rises, whilst its depth beneath the surface increases. This rule is often true even when there is a want of uniformity in the strata or in the configuration of the ground, though so much depends upon the inclination the beds have, and their relative permeability, that it is impossible to lay down any precise rules as to where water may be struck in any but the simplest cases.

This is still more evident if the rocks are contorted, fissured or faulted.

Some special cases may be given however. Thus if a porous stratum overlies an impervious one, the water descends through the former until it reaches the latter. Now as the lower stratum is level, or slopes towards its outcrops, or is depressed in the middle, the water which soaks through the porous stratum will eventually appear in the form of springs near the upper line of the outcrop of the lower stratum, or be mostly stored in the depression mentioned of this stratum. Unless the porous stratum is very shallow, wells may be dug in it, especially in the last case mentioned, with the expectation of getting a good supply of water.

Where the porous stratum is covered by an impervious one, it holds less water than in the previous case, for it now receives no water except along its outcrop.

Where such porous strata, however, are of great extent and have a considerable outcrop (it may be in remote districts) a good supply of water may be expected.

In the latter case, if the porous stratum is again underlaid with an impervious one which is depressed in the middle, large quantities of water will collect in this basin under considerable hydrostatatic pressure. If this pressure is sufficient to send water to the surface through a well hole, the result is an artesian well, which wells are much resorted to in some countries.

In this State we need have no fears of a water famine if the various sources are utilized. In the Quarternary sand of

the eastern portion of the State, wells only 15 feet deep are common, though the underlying Tertiary marls and older rocks may cause exceptional features. In the middle and western portion of the State, the rocks are sandstones, slates and various crystalline rocks, which are often fissured, faulted, contorted or intersected by trap dykes; thus causing abnormal features: still, as the dip except in the sandstone formation is often considerable, there is not generally much difficulty in finding water on digging for it; so that the "diviner" with his witch hazel twig generally finds his predictions verified. Perhaps it would be the same if he did not invoke its mysterious powers to assist him! In the older rocks, the water often collects in fissures. Instances are known where pumping from one well affects a remote one; whilst, on the other hand, owing to faults, dykes, change of dip, etc., wells very near together seem to have no connection.

As a rule, the wells are deeper in the older rocks; for, as the latter are more impervious than the sands of the later formations, less water is absorbed by them—more running off into the streams—therefore we should naturally expect to go deeper for a constant supply. Other things being equal, the deeper the well the purer the water, as it has filtered through a greater extent of earth.

The earth is thus a vast sponge, ready to afford water when tapped, that is generally of a better quality too than lake or river water in the vicinity.

Prof. Nichols (see "Filtration of Potable Waters,") has observed, that even when the well is situated near a stream, that "the water is generally clear and colorless, of a nearly uniform temperature, and differs in chemical character from that of neighboring streams or ponds, generally being somewhat harder."

On lowering the level of the water in such basins by pumping or otherwise, the ground water level is lowered next the basin to the same extent; but it is found that as

we proceed from the well or basin, that this level is lowered less and less, until we reach a point which is not affected when the level of the water in the basin is kept at a certain minimum height, the friction and capillarity balancing gravity here; supposing always the rain fall not subject to much variation. In case of drought, of course the whole ground water level would be lowered.

As an illustration of the above principle, it was found on the Elbe, that when the water in a well, dug in an alluvial deposit, was kept constanly 8.2 feet below its normal level, that the height of the ground-water was affected in every direction for 200 feet only.

Large basins, near streams, are often used as the source of water supply of whole towns. Now it is evident that if the water level is lowered in such a basin that since the water level in the intervening bank is lowered, that the river water will have a tendency to flow towards the well to make up the deficiency, unless the bottom and sides of the river have become coated with clay to such an extent as to be impervious, which is very apt to be the case unless the stream is very clear, or has a rapid current. Known examples seem to show little or no contamination from the river water when the basins are built 100 to 200 feet from the river. The basin is constructed *next* a stream, as there is apt to be a greater flow of ground water there; besides the water in the stream can make up any deficiency by use of proper constructions.

Filtration.—This *natural filtration* of water through the soil, when the latter is good, is more efficient than any system of ARTIFICIAL FILTRATION, which, when practiced on a large scale, generally consists in passing water through layers of sand and gravel about six feet deep. The finest sand is put at the top, the upper portion of which catches most of the suspended matters, and by the oxygen condensed in its pores, frees the water of a small portion of its organic matter.

As the sand becomes clogged, it is scraped off at top and fresh sand added.

It is well not to cause the water to flow through the filter at a rate greater than fifty gallons per square foot of surface per day. The water is usually several feet deep on the filter bed. The beds are scraped about a dozen times a year, oftener in summer than in winter.

When possible, it is best to construct settling-basins where the water can deposit much of its sediment before passing on to the filter beds.

In some rivers, the particles of clay in suspension are so fine as to readily pass through sand and even filter paper. In such cases, charcoal pounded fine is the only resource. The action of a sand filter is two fold, mechanical and chemical:

1st. Mechanical, in that suspended matters too large to pass through the pores of the filter are caught, as in a net; likewise much sediment that would otherwise pass through sticks to the grains of sand, due to the property of adhesion.

2nd. Chemical, for although sand filters have practically no action on dissolved mineral matter, yet an appreciable quantity of organic matter in solution, particularly certain kinds, are removed by filtration through them.

An experiment that any one can perform will illustrate this: Add a few drops of sulphate of indigo solution to some clear water; the water assumes an intense blue color, which color it retains on filtering through an ordinary filtering paper. But if we strew over the filter paper some powdered charcoal (animal charcoal is best) the water comes through perfectly colorless. If we use earth in place of the charcoal, the water that passes through it is slightly colored, thus showing that earth is not so powerful an agent as charcoal. Now, evidently, here the earth or the charcoal have exercised a different influence from the filter paper alone. The filter paper will catch *suspended* matter. Thus muddy water passed through it may become clear, but it does not alter

chemically the substance in *solution*. We have just seen, though, that earth or charcoal does, and the usual hypothesis to account for this fact is that "porous substances condense gases—air, oxygen, etc., in proportion to the extent of their interior surface," and this oxygen actually destroys by *slow combustion* the substance in question. The enormous amount of surface to volume of porous charcoal or piles of earth permits the condensation of a large amount of gas which stands ready to attack any chemical body that can be decomposed or altered by it.

Of course this chemical action must diminish the more the longer the filter is in action, as the oxygen is not so readily replaced when the filter is covered with water. If water is really *polluted* by sewage matters, it has been shown that it may be improved materially but not perfectly purified by filtration. It is, therefore, pertinent to ask, what amount and kinds of organic matter found in water render it unfit for drinking?

Evidently, we must consider the two questions together. Organic matter, *per se*, cannot always be deleterious, otherwise soup would have to be ranked as poison. It is stated that the waters of the Dismal Swamp, saturated with organic matter, is actually preferred by sea-going vessels to purer waters. Chemistry is perfectly able to determine the mineral salts dissolved in water, and medicine can pronounce upon the amounts that may be taken into the system without injury. Chemistry can likewise determine the amounts and kinds of organic matter in any water, and if the source is known to be bad, or the organic matter (especially the albuminoids) in excess over good potable waters in the vicinity, the chemist is able to form an intelligent opinion, at least as to the "possible amount of germ" or disease producing power of the water.

London drinks Thames water principally, though "above the point where the supply is abstracted the river is contaminated by the excrements of more than 200,000 human beings."

Those who favor this water, claim that a polluted river purifies itself in its onward flow, the noxious matter being oxidized as it is tossed to and fro by the current and thus rendered innocuous, besides being more and more diluted. Again, fish eat fresh fecal matter, and vegetation can abstract large quantities of it. Still, it is doubtful if this natural process is continued long enough to thoroughly destroy the hurtful part of the sewage.

Now can this Thames water be regarded as a fit source for water supply, having once been contaminated to a certain extent? "The noxious part of sewage is that which is held in mechanical suspension, and these globules are beyond the reach of the chemist, and, to a great extent, of the microscopist. There are only two processes by which it can be effectually removed; the one is boiling for a long time, and the other is by distillation, both impracticable on a large scale." "No process of filtration that has yet been devised will remove choleraic dejections from water." (Humber's Water Supply, p. 19.)

The organic matter is not then considered as fatal in itself, but as dangerous, when of certain kinds, as affording a refuge and breeding ground for the poison germs that attend an epidemic. A person may drink even diluted sewage with but slight inconvenience until this germ is once planted in it, when at once his beverage changes to a rank poison.

Whether we accept the germ theory or not, it is admitted that drinking foul water and breathing impure air debilitate the system and thus render it less able to withstand epidemics. Let us then follow the natural instincts and avoid polluted air and water, especially as North Carolina can afford the pure articles in such abundance.

Lead Poisoning.—There is one source of poisoning that may be considered by itself—*lead poisoning*, due to the use of lead cisterns and lead pipes.

Soft waters that contain oxygen oxidize the lead and then dissolve the lead oxide formed. Hard waters, containing free carbonic acid, form, on the contrary, carbonate of lead, which is only soluble to the extent of one part in seven thousand, unless there is much free carbonic acid present. Clarke's softening process lessens the action of water on lead. Peaty matters form a sort of protecting coating on the lead pipe that is very efficacious in preventing further action on the lead. One-tenth of a grain of lead per gallon of water may produce lead poisoning in time.

The presence of lead in water is easily detected by passing a current of sulphuretted hydrogen through a deep column of the acidified water. If the liquid becomes tinged of a brown color, it is due to the formation of lead sulphide. What is the remedy if the water is found to act continuously on the lead? Simply abolish the lead cisterns for slate, or stone ware, or galvanized iron cisterns, and replace the lead pipes by wrought iron pipes with screw joints. The tin lined lead pipe has not proved satisfactory; a small flaw exposes the lead, a galvanic action between the two metals is commenced and the water is speedily poisoned.

It is of the greatest importance to observe that no cistern or water pipes should be placed where sewer gases may pass either through or over them, in contact with the water, since water is very absorbent of such gases.

Cistern Water.—Where rain water is used as the source of supply, it is collected from the house roofs and stored in *cisterns* of wood or brick in cement. The cistern, if of wood, should have a circular form; if of brick, any convenient form can be used, provided the earth is well rammed behind the walls, to enable the latter to withstand the outward pressure of the water. The cistern should be covered and ventilated.

The rain water as it descends brings down many impurities from the atmosphere, such as soot, acid fumes, oil, etc., particularly in the manufacturing centres; besides if or-

ganic impurities in the shape of dust, such as horse manure, etc., cover the roof, the water is further contaminated before it reaches the cistern. The character of the roof likewise, whether lead painted, formed of new shingles or decayed ones, etc., must be considered. We thus see that cistern water is not necessarily perfect, though it is probably better than well waters, for while it has not had the benefit of the natural filtration of the latter, still it has taken up no new salts from the ground, and has certainly escaped sewage contamination.

Nevertheless, it should be filtered before being used. This is effected in various ways. One plan, when the brick cistern is used, is to divide the cistern by a porous wall into two unequal parts. The foul water, let into the larger division, filters through the porous wall into the smaller division, from whence it is pumped over the house. The porous wall may be made of soft bricks, or of some filtering material, as porous tiles or blocks of animal (bone) charcoal, that may be placed in a frame which can slide in groves and be readily replaced when the filter has become clogged up.

The brick wall, although very efficient at first, becomes clogged up in a few months by solid matter, consisting, amongst other things, of insects, worms, etc.; so that the filtration then is rather an injury than a benefit, as chemical analysis has demonstrated. The solid matters that settle at the bottom of cisterns should, of course, be removed whenever practicable.

Domestic Filters.—With regard to domestic filters of any kind whatsoever, it may be observed that the filtering material requires renewal every few months.

The following is an extract from the "Sixth Report of the River Pollution Commissioners of England:"

"It cannot be too widely known that, as a rule, domestic filters constructed with sand, or sand and wood charcoal,

are nearly useless after the lapse of four months, and positively deleterious after the lapse of a year."

"Of all material for domestic filtration, with which we have experimented, we find animal (bone) charcoal and spongy iron to be the most effective in the removal of organic matter from water."

"The removal of mineral constituents, and the consequent softening of the water, ceases in about a fortnight, but the withdrawal of organic matter still continues, though to a greatly diminished extent, when the filter is much used, even after the lapse of six months."

"We found that myriads of minute worms were developed in the animal charcoal, and passed out with the water when the filters were used for Thames water, and when the charcoal was not renewed at sufficiently short intervals, a serious drawback to its use."

The spongy iron is free from this trouble, but the filtered water, especially the first portions filtered, contain iron ; and the softer the water the more iron dissolved.

On the whole, it would seem that for hard waters "Bischop's Spongy Iron Filter" is best, though the animal charcoal is an admirable material, when renewed every few months. Chemical analysis can alone tell when the filter has ceased action.

Both materials (spongy iron and animal charcoal,) remove about the same quantity of "albuminoid ammonia," say one fourth, as a mean of some very careful experiments, (Nichols on Filtration of Potable Water), this substance being taken as the measure of the suspicious organic matter in solution.

From an analysis by Bischof (Humber's Water Supply) it would seem that the spongy iron (a metallic iron reduced from an oxide without fusion, and hence in a loose spongy state) was a more efficient agent than "magnetic carbide" and "silicated carbon," two other materials that have been used with success.

If animal charcoal is used, it should be in lumps in pref-

erence to blocks, though the latter gives good results. An admirable filter, that may be used in any cistern, consists of a metallic vessel with a perforated bottom, filled with animal charcoal and having a pipe leading from the top, which must be below the level of the water in the cistern. The water of the cistern passes up through the perforated bottom, then filters through the charcoal and is drawn off by the pipe when it is needed. The advantage of this arrangement is this: the suspended particles are caught mostly at the bottom of the filter and may become detached from the filter, especially if water is forced through it from the top in a downward direction at intervals. The filter can of course be taken out at any time and the material ærated or renewed. Many other materials have been used for filters of small size—sponge, sand, cotton, flannel, earthenware, common charcoal, etc. The small size filter acts simply as a strainer in a short time, and requires frequent renewing, otherwise it is worse than useless. Makers of all kinds of filters, however, do not hesitate to aver that they are self-cleansing, perfect, etc., etc., which, we have seen, is opposed to the best and latest scientific research on the subject. Let the householder be guided by the facts.

Where nothing better is at hand, water may be filtered through a box perforated at the bottom, containing clean quartz sand, resting on a plate of porous earthenware or on bricks placed on top of the charcoal. Expose the filter to the air from time to time.

Public Systems of Water Supply.—It will probably not be long before our cities will demand purer water than can be supplied by the wells and springs now used; many of them being, without doubt, polluted by the many impurities thrown on the surface. This involves a *public system* of water supply, with its attendant system of reservoirs, filter beds, pipes, hydrants, etc. In view of such contingency, it may not be out of place to mention some of the requirements that such a system should fulfill.

The water may be obtained from lakes, rivers and streams, springs and wells, impounding reservoirs often being used to collect that which falls on the hill-sides into one place.

This water may be conveyed for distribution (Rawlinson's Suggestions to Local Sanitary Boards, England, p 20,)—

"By means of open conduits (before filtration);
" " " covered* " (always after filtration);
" " " cast iron pipes under pressure.

A water supply may be gravitating, or the water may be pumped by steam power. The relative economy of one or the other form of works will depend on details of cost and quality of water; as a rule, gravitating works require the largest capital. The annual working expenses of a pumping scheme may, however, be greatest. Reservoirs for service distribution should be covered.

If filters are used, the water should not be exposed in open reservoirs and tanks after filtration.

Cast iron pipes, properly varnished, should be used for street mains. Lead should not be used with soft water, either in service pipes or in cisterns. Wrought iron tubes with screw joints may be used for home service.

Water at and below six degrees of hardness is considered soft water; above this range, water is termed "hard."

These "suggestions" of Mr. Rawlinson, (Chief Engineering Inspector to the local government board, London,) are valuable, especially as they represent the best modern thought on this subject, and may tend to prevent fatal mistakes in designing water supply systems.

As he says, "The great modern improvement in water supply is the delivery by *constant service*, and at *high pressure*, over the entire area of a town, and into every house, cottage and tenement, and should be secured where practicable."

The "constant supply at high pressure" permits con-

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*Covered, to prevent the growth of vegetable organisms.

sumers to draw water from the pipes at any time, and can be made so efficacious in the extinction of fires as to diminish their destructive effects most materially. Fire engines are not needed with such a system. It is said that in Paris, owing to the excellent organization of the fire department, that a destructive fire is almost unknown. The "*intermittent supply*" does not offer these advantages. House cisterns are required to stow the daily allowance of water, which is only supplied at certain hours. The cisterns, if neglected, may not be supplied with water, or they may leak, or absorb foul gases, and finally suffer from want of cleanliness.

There is, besides the high pressure due to a sufficient elevation of the reservoir above the town, the "*Holly System*" of maintaining this high pressure in the pipes by *steam power*. The pumping machinery is placed near the water, which is pumped directly into the mains, the pressure being kept constant, or increased or diminished at will.

This system is highly spoken of wherever it has been tried.

Source of Supply. Available Rainfall.—In any one of these systems, it is a first requisite that the source of supply shall be constant and unfailing. Where a large stream is used as the source, the amount that can be depended on in the dryest seasons may be estimated with some degree of certainty. Where small lakes, springs, wells and small streams are used as the source, we have to depend, more or less, on the observed rainfalls for the different seasons, in conjunction with the measured flow of the streams if any to form, at best, only an approximate estimate of the yield.

Such observations should be conducted over a period of twenty years if possible, to include all fluctuations; but as a rule, in this State, we have only a few years observations of rain fall, and only one or two of the flow of streams to found an estimate upon of the probable yield of water over a given drainage area.

Let us suppose that an embankment is thrown across a

valley, to form a reservoir, into which shall be stored all the water that drains into the valley from its "catchment ground," whose area can be readily computed, as it is bounded generally by well defined ridge lines and the embankment in question. Now the yearly rain fall in different portions of the State varies from 20 to 60 odd inches, the average being high, over 45 inches certainly. If all of this could be collected into reservoirs, the amount would be given by simply multiplying the catchment area by the depth of the rain fall; thus, if the catchment area was one square mile, 27,878,400 square feet, and the depth of rain fall one foot, we should have 27,878,400 cubic feet in a year or 76,379 cubic feet in one day for the supply. But in practice we are very far from securing the whole rain fall, the reason for which can be made plain by the following considerations.

Let us first suppose the catchment ground to be impermeable and free from vegetation; then any rain that falls all flows into the reservoir, except that lost by evaporation; the latter being less *as* the surface is steeper, the temperature lower and the drainage area smaller.

If, however, the surface of the ground is *pervious*, as is usual, then a portion of the rain fall sinks into the ground, to appear again as springs, and thus drain ultimately into the reservoir, or else to pass off by some subterranean stratum to other outlets. In this case the amount lost by evaporation is less *as* the ground is more absorbent and better drained, the slopes steeper, and the temperature and area smaller. If now we suppose the earth more or less clothed with vegetation, the latter absorbs and partly evaporates still more water. The conditions of the problems are thus seen to vary greatly for different localities, with the season of the year, and it may be added, also with the winds and relative humidity of the atmosphere.

In England, where observations have been conducted for years over many distinct catchment basins, the loss due to

evaporation and absorption, has been found to range from nine to nineteen inches per annum, and it is the practice to consider as available no more than the mean fall for three consecutive dry years, (which is found to be, as a rule, $\frac{1}{6}$ less than the average rain fall,) after subtracting the loss by evaporation. Thus, if the mean fall for three consecutive dry years is about forty inches, and if the loss by evaporation and absorption is put at 20 inches, this would leave 20 inches of rain fall that could be utilized if it was *all* stored.

Observations on Lake Cochituate, Mass., water shed of 12,077 acres, from 1852 to 1875, gave a yearly rain fall varying from 35 to 69 inches—average 50, and the percentage of this received into the lake 25 to 74—average about 45. It is nevertheless recommended by some good engineers that not over 12 to 15 inches of rain fall be counted on as available in the United States, which is less than Humber allows.

The evaporation from the surface of *the water in the reservoir*, in dry seasons, averages about $\frac{1}{10}$ inch daily in England, whilst it is as much as $\frac{1}{2}$ inch in some localities in India. The annual loss in England is put at 20 to 25 inches. It is, of course, much more in small and shallow ponds, which can be more readily heated, than in extensive reservoirs or lakes. Trautwine says that the daily loss from evaporation in the three warmest months of the year will rarely exceed $\frac{3}{10}$ inch in any part of the United States. This is probably too high, for the same authority found in the tropics over a pond 8 feet deep, a loss of only 2 inches in 16 days, or $\frac{1}{8}$ inch per day. The thermometer reached 115° to 125° in the sun every day. It is evident from the foregoing the importance of early making observations in each locality for as long a period as possible, in order to ascertain the ratio of the "available" to the "total" rainfall. Rankine says that this ratio is about 1 for hard rocks, roof surfaces, paved streets, &c., $\frac{8}{10}$ to $\frac{6}{10}$ for pastures, $\frac{5}{10}$ to $\frac{4}{10}$ for flat cultivated country, and 0 for chalk. It follows that a

catchment basin is best located in the older formations, consisting of hard rocks, whilst wells suit best the more previous and recent deposits. London is even now preparing to give up the Thames water altogether and to draw her supply from her underlying chalk beds.

It is important to note that the most reliable method of ascertaining the available rainfall is to measure the *actual discharge* of streams that drain a given water shed. Then by comparison with the total rainfall on the water shed, we find the actual amount lost by evaporation and absorption of the ground.

No town which contemplates a public water supply should neglect to have such observations made, covering a period as long as possible, to take proper account of droughts, &c.

Consumption per Head.—Statistics show that in England the *daily amount of water used in the towns and cities varies from* 15 *to* 50 *gallons per head*—30 being regarded as a full allowance. In the United States the daily consumption per head varies from 25 to 120 U. S. liquid gallons of 231 cubic inches (1 cubic foot—7.48052 gallons); and it is recommended by some to allow 40 to 50 gallons per head for smaller cities, and an increasing amount as the population increases.

It is very plain, from the records, that an enormous waste occurs in our cities, and special attention is now being directed to it. Where inspections, or water meters have been tried, the amount consumed has often been reduced to half and even one-third the original amount. Humber estimates that 20 to 25 gallons is a liberal allowance. Even if we assume double this, it still behooves us to take every precaution to avoid waste by the use of meters or otherwise; else the large yearly cost of the water supply may be needlessly doubled or trebled.

Reservoir Capacity.—Well, assuming, say 45 gallons, the *daily demand* on a reservoir is made up of the 45 gallons

× number of population, plus the daily evaporation from the surface of the water, plus any compensation water to mill owners or others. Subtracting from this the dry weather flow of the streams discharging into the reservoir, we get "*the excess of the demand over the supply*" in dry months; and this multiplied by *the number of days storage* of the reservoir, gives its *available capacity*, or the volume it must contain between its highest and lowest working levels. Some advise that every storage reservoir should, if possible, contain six months of the excess of the daily demand above the daily supply for the dryest consecutive six months. Some English engineers formulate the following rule, as the result of considerable experience: "The number of days storage of reservoir" equals the number 1,000 divided by the square root of the rainfall in inches for three consecutive dry years. Thus, if this rainfall is 36 inches, the reservoir should contain $1{,}000 \div 6 = 166.7$ days storage; that is, 166.7 times the excess of the demand over the dry weather supply.

The following table (see "Engineering News," Aug. 23, 1879,) will show the great disparity between the least and greatest flow of streams:

NAME OF RIVER.	Drainage Area in Square miles.	FLOW IN CUB FT. PER SQ. MILE.	
		Greatest Flow.	Least Flow.
Connecticut, ...	10,234	20.27	0.51
Merrimack, ...	4,136	23.40	0.53
Schuylkill, ...	1,800		0.21
Tyne, England, ...	1,100	30.23	
Passaic, ...	981	20.33	0.23
Croton, ...	339	74.87	0.15
Concord, ...	352	12.64	0.17
Hackensack, ...	84		0.33
Sudbury, ...	76	41.60	0.05
Croton, W Branch,..	20	54.43	0.02

"These figures show that on large drainage areas the proportional flow is less in freshets and greater in dry seasons than on small areas."

The "least flow" given above is probably the least flow on any day of the dry season. If, however, our reservoir is to contain, say 6 months supply, then we desire to know the least average flow for any 6 months during 20 or more years. Suppose this to be 0.2 cubic feet per second per square mile of drainage area, or 17,280 cubic feet per day per square mile.

Suppose a population of 10,000 consuming daily 6 cubic feet (45 gallons, say) per head, or 60,000 cubic feet in all; and that the loss by evaporation from the reservoir of 10 acres say, is $\frac{1}{8}$ inch daily, or about 5,000 cubic feet. The total daily demand is thus 65,000 cubic feet, which is about 48,000 cubic in excess of the supply from the stream; so that if the reservoir is to contain 6 months=180 days of this excess, its available capacity must be 48,000×180=8,640,000 cubic feet, or an average available depth over the 10 acres of 20 feet.

It is evident that if the daily demand, as above, is 65,000 cubic feet, the yearly demand thus being 23,725,000 cubic feet, that but little over 10 inches of rainfall over the 1 square mile of drainage area has been secured, since 10 inches on a square mile gives only 23,232,000 cubic feet. This is certainly within reasonable bounds.

No allowance is made above for compensation to mill-owners.

Of course, by building the reservoir of sufficient capacity the whole of the rainfall, minus the loss by absorption, evaporation and leakage, can be utilized; but it has not been found desirable to build such huge reservoirs in actual practice, so that much of the rainfall is purposely allowed to run off.

Sources of Water Supply in N.C.; Maintenance of Purity.—This State is abundantly supplied with unfailing sources of water supply in her many rivers and lakes, not to speak of the underground water, which hitherto has been the only source used in the supply of her largest towns. What a contrast do the rivers and streams of England—

many of them fouled to inky blackness by the refuse of thousands of manufactories—present to our own waters, teeming with fish and drinkable almost everywhere. It is to be hoped that the enacting of wise laws will maintain their purity, by forbidding any injurious waste or crude sewage from entering them. If this system is inaugurated from the beginning, much trouble may be avoided. England now is making a brave effort to *regain* the pristine purity of her streams; let us be careful not to *lose* this thing of beauty in our own waters.

The foregoing notes are very brief, but they may contain some useful hints to our larger towns and cities, who will sooner or later abolish the polluted well and adopt a public system of water supply.

CHAPTER IV.

WATER SEWERAGE.

Then will likely follow the complex system of *water sewerage,* which is now regarded as the best for the largest cities; though it is admitted that it is a delicate machinery and requires the greatest care in its manipulation.

This system has been so thoroughly studied that a sufficient literature exists on the subject to answer the needs of practice; so that it is needless to enter into any very technical discussion of it here.

Conditions that the system should fulfill.—The object to be accomplished by the system is to carry all offensive matters underground, and *as rapidly as possible,* out of the city, by the aid of the water used in the houses and the rain water that falls. The proper carrying out of a system of this kind requires the aid of enlightened sanitary engineers of experience; above all, in the general design. Jenkin's "Healthy Houses," already referred to, is sufficient to show the general reader, not only the cause of many failures, but the remedy; in fact some of the conditions that the system should fulfill. Let it be borne in mind by any town contemplating the water system, that an error in design, like the bad foundation to a structure, is often very difficult to remedy.

Special emphasis is laid on the principle, that the sewage should be carried out of the town limits quickly—say in 24 hours, or less, when practicable. This is effected by a correct adjustment of the size and shape of the sewer to its fall, having assumed the total amount of sewage that is to be provided for daily. The question is one of hydraulics, and may be solved by the use of well known formulæ for the flow of water in channels.

Example.—As an illustration, take the following, from "Rawlinson's Suggestions": "The sewage of a town or village will consist of waste water and excreta from the houses, and the volume, in round figures, may range from 100 to 250 gallons per day from each house. This volume will probably flow off in about eight hours, so that the sewers must provide for not less than three times this volume, if even every drop of roof and surface water can be excluded. As this cannot in all cases be accomplished, the sewers should provide for not less than 1,000 gallons from each house; or for a town of 1,000 houses (5,500 population) have a delivering capacity of about 1,000,000 gallons (daily). An outlet sewer of 2 feet diameter, laid with a fall of 5 feet per mile, will deliver upwards of 2,000,000 gallons, flowing a little more than half full. Lesser diameters will answer where there are greater falls."

A 2 feet sewer thus provides for doubling the population in a few years.

Now 100 to 250 gallons per day, from each house, containing $5\frac{1}{2}$ persons, corresponds to from 18.2 to 45.5 gallons per day for each person, which figures represent about the extremes in English practice; 30 gallons being the usual allowance, excluding rain water.

In the case above, the velocity of the sewage of 11,000 persons is about 2 feet per second, which is the minimum velocity in order that so small a sewer may be *self-cleansing.*

As the velocity is less for the real population of 5,500, especially if they use less water than 1,000,000 gallons, the inclination of the sewer should be increased if possible, or "flushing" will have to be resorted to, or the sewer must be made smaller than the 2 feet diameter, to secure the proper velocity to make the sewer self cleansing, and to prevent the formation of the poisonous sewer gases, which are always formed when the progress of the sewage out of the town is slow, in spite of all the ventilation schemes that may be tried.

A circular sewer, one foot in diameter, running half full, at an inclination of 1 to 600 will discharge 46.3 cubic feet per minute, at a velocity of 118 feet per minute, equivalent to a discharge of 167,000 gallons (in round numbers) in 8 hours. This is slightly over the discharge of 5,500 persons, allowing 30 gallons to each person, so that this one foot sewer would suffice if rain water is to be disregarded.

Amount of Rain Fall to Pass into Sewers.—Let us next ascertain the size of a sewer on the supposition that the town is one square mile in area, and that a rain fall of one inch in 24 hours actually drains into it. The rain fall is 2,323,200 cubic feet in 24 hours; or at the rate of 1,613 cubic feet in one minute. By use of proper formulæ, it is found that an egg shaped sewer, $3\frac{1}{3}$ by 5 feet, running full, will discharge the water at a velocity of $3\frac{2}{3}$ feet per second, the inclination being taken, as at first, at only 5 feet to the mile.

We can now readily see, by this particular example, how much the size, and hence the cost, of sewers is increased by making provision to receive the rain fall. It is, of course, far more expensive to provide for the exceptionally heavy rain falls (as "6 inches in 2 hours," etc.,) which sometimes occur. Sewerage systems in this country do not provide for such exceptional rain falls.

The London sewers were constructed to carry $\frac{1}{4}$ inch rain fall in 24 hours, at the time of maximum flow of sewage, larger amounts being provided for by storm water overflows.

It is found that different soils, or surfaces, have not the same absorptive power; thus in London the sewers in some sections deliver one-half the rain fall, whilst in entirely paved streets, nearly the whole of the water is drained into them.

Latham says that in Croyden, the soil being porous, gravel overlying chalk, "the amount of rain contributed by a storm of .72 inch in 12 hours, did not yield more than one-tenth of it to the sewers." More impervious districts required the full allowance of 1 inch in 24 hours, together

with the sewage. In Dantzic, which is sandy and flat, $\frac{1}{4}$ inch in 24 hours, together with 2 cubic feet of sewage in 8 hours was assumed as the basis for computations.

It is plain from what precedes, that any town contemplating a sewerage system, should be able to form some judgment as to the amount of rain water to be admitted to the sewers, if any at all.

Argument for and against excluding rain water from sewers.—The reasons for and against separation of the rain water may be stated as follows:

For Separation.—It is urged that even if a distinct set of sewers is used to convey away the rain water, that it is cheaper; since the rain water sewers can discharge into the nearest stream (thus giving it its natural volume) and can thus be made shorter than the sewage conduit, which is often carried a considerable distance; besides the sewage conduit is very much smaller and therefore cheaper in this case. Again, on account of the small size of the conduit, the sewage is carried out of town much more quickly; thus preventing that stagnation which sometimes occurs in large sewers, having only a thin film of sewage flowing slowly over the bottom, much of the solid material being deposited to decompose and generate the most hurtful gases.

Likewise, the manurial value of the sewage is increased and any expense of pumping very much diminished.

Against Separation.—It is urged on the other side, that chemical analysis shows that, in large cities, the storm waters wash away so much filth as to render the water as impure as the sewage; so that, at least, the first portions of the rain fall should be admitted into the sewage conduits, though the balance may be passed into the streams. Also there are objections to the use of so many pipes in the streets; two sets of sewage pipes, with smaller drains often crossing, besides gas and water pipes; the drainage pipes too having to be laid everywhere with a fall. It is plain, however, that if the surplus of the rain water is to be allowed to go where

it can, that the old channels should at least be so much improved as to prevent flooding of cellars and formation of any stagnant pools anywhere. So much separate drainage should at least be insisted on.

It is certainly in the line of simplicity to adopt but one set of sewers; and experience shows that in most towns it rarely causes any inconvenience from flooding.

If drainage pipes have already been laid, they should not be abolished, even if sewers are afterwards projected.

Subsoil Drainage.—If there is but one sewer system, then the *subsoil* must be drained by small pipes, simply butted together at the ends, so that the subsoil water can enter. The pipes must be placed *on top* of the sewer pipe to prevent any infiltration from the sewer, which often happens if they are placed below the sewer. This subsoil drainage is especially necessary in a retentive soil, to render the soil porous, so that it can more effectually do its work of oxidation on any gases that may pass through the sewer.

The latter should be rendered as impervious as possible, for leakage through bad sewers into the ground soon saturates it with the vilest poison, that invariably produces harm as soon as it can find an outlet to the outer air.

Form, Inclination and Ventilation of Sewers.—Small circular sewers can be made of earthenware pipe, larger ones of brick in cement or of concrete, and egg shaped, to give a greater velocity to a small flow. Main sewers should not be laid at greater inclinations than cause a velocity of six feet per second, if possible, to avoid the cutting out of the bottom of the sewer by grit and other solids. The location of the main outlet sewer determines, to a great extent, the positions of the other sewers, and should receive special study. House drains should be trapped and ventilated between the house and sewer. The main sewers should be ventilated by direct communication with the external air, at least every 100 yards. This prevents that partial and noxious decomposition which occurs in close places having a limited

amount of air. "In fully ventilated sewers the sewer air is purer than that of some stables, or even in a crowded public room."

Nothing is so much insisted on in the best modern practice as thorough and complete *ventilation* of all sewers and house drains and pipes.

House Pipes.—Above all, in this water system, the house connections require the greatest care in their construction and design to keep the lurking poison out of the house; and it is regretted that want of proper diagrams necessitates the ignoring of this branch of the water system in this paper.

Disposition of Sewage.—Having briefly considered some points of general interest in connection with the design of sewerage works, let us next enquire what is to be done with the sewage.

The plan most in vogue in this country is to discharge the sewage matter into some stream, which may thus be regarded, in one sense, as the continuation of the sewer.

In the case of tidal waters, however, if the refuse is emptied near the city it floats up and down the city past it, giving anything but an air of cleanliness to the eye, or of satisfaction to the nose.

In England, the law now "requires that rivers and streams are not to be polluted by the admission of crude sewage, even from existing sewers."

Rawlinson states that up to October, 1878, "there are about 87 towns, districts, parishes, and places whose sewage is disposed of by *irrigation*. There are 23 towns, &c., whose sewage is disposed of by *precipitation*, treatment with *chemicals*, and partial *land-filtration*. There are 24 towns, &c., whose sewage is disposed of by ruder and more imperfect modes of filtration, as through charcoal, wicker work and straw. There are 16 towns, &c., whose sewage is disposed of by mechanical subsidence only." The sewage is first carried by the outlet sewer to the "sewer farm," where, if nec-

essary, it is pumped into large tanks, to be then treated according to some of the methods given above.

Irrigation and Filtration.—The best method probably is *irrigation*, or *filtration* through a porous soil.

This plan might be carried out by passing the sewage at intervals from large tanks, where it is collected, through hundreds of earthenware pipes, loosely jointed, placed about one foot below the surface of the ground and in parallel rows. The sewage leaks through the joints into the surrounding soil, which purifies it by absorption and oxidation. A better known method consists in simply passing the fluid sewage on to ground, deeply drained. The purified water runs off in the drains.

By distributing the sewage over a sufficient extent of surface, it is found that the soil does its work perfectly; being aided, moreover, by the growing vegetation, taking up much of the sewage through its roots. The purification, though, is principally due to the earth, which has the property of absorbing and condensing gases, such as air, &c.; so that each little particle of earth is surrounded with condensed oxygen, which acts upon the sewage matter the instant it comes in contact with it, and oxidizes the organic part,—throwing off some of it into the air—not as poisonous effluvia, which is the result of decomposition with a limited amount of oxygen, as in close drains, but as harmless aqueous vapor, carbonic acid and ammonia. The amount of oxygen absorbed by the soil is not large, but it seems to be replaced as rapidly as it enters into combination, and thus to furnish an indefinite supply to the matter with which it combines. (See Johnson's "How Crops Feed," pp. 218 168, etc.)

It must then be distinctly understood that the putrescent substances are not simply absorbed (as usually stated) by the earth or charcoal, or other porous material; but are chemically changed—oxidized or burnt up—so that their objectionable features are no longer perceived; the nitrogen, etc.,

is thrown off into the air, or passes off in the water as nitrates, or nitrites, so that the earth ultimately has about the same constitution after its use in the manner indicated as before.

At Merthyr the effluent water from the filter beds was analyzed by Dr. Frankland, showing that when 230, 500 and 1,200 people were draining on to them per acre, the effluent water was respectively 30, 16 and 3 or 4 times purer than the standard of fair potable water, so far as chemical analysis is taken as the criterion.

It is thus seen how effectually surface soil, where there is plenty of air, does its work. It is warmly advocated by Geo. E. Waring, Jr., (see "The Sanitary Condition of Dwelling Houses," Van Nostrand,) to get rid of all liquid refuse, about the country or town house, where there is no system of sewers, by passing it through loosely jointed pipes, laid about one foot below the surface in the back yard. He states that the system has been found to work admirably, winter and summer wherever tried.

It may be stated that the efforts that have hitherto been made to utilize the fertilizing properties of sewage have not been profitable, unless in the way of irrigation. Fine crops have been raised on such sewage farms; so that where intermittent filtration is adopted, it is advisable to combine sewage farming with it to lessen the expense.

The Chemical Processes used so far have not been found to purify the sewage thoroughly by themselves, so that natural or artificial filtration must supplement any chemical treatment. Besides this objection to the chemical method, its cost and difficulty of manipulating the accumulations of sewage sludge both make against it; still much of this sludge must be removed in some way before filtration can be employed.

In seaboard towns, the natural outfall for the sewage is the sea. If possible the sewage should be carried to such a distance as not to be brought back to the town by wind, tides

or current. The same remarks apply to towns situated on tidal streams and estuaries.

Caution to our Cities.—Most of our large towns have a clean slate for sewerage systems. Let not a single sewer be built until a competent engineer plans the entire system, otherwise the sewers may have to be torn up eventually, or the engineer may be considerably embarrassed in his designs. The Secretary of the Board of Health, Dr. Wood, writes of Wilmington, that "there is an incipient sewer system here which promises to be a great nuisance, from the beginning they have made with it." It seems a pity for Wilmington to make a botch of it the very first move.

THE LIERNUR SYSTEM.

In a paper read before the Austrian Society of Engineers, Vienna, (see Baldwin Latham's "Sanitary Engineering," Am. ed.) Mr. J. Chailly says:

"The two conditions of removal without producing disagreeable odors, and carrying off the matter in short periods, are almost entirely fulfilled in Lieurnur's Pneumatic Sewerage system, in which the iron waste-pipes, which are water-tight and air-tight, are united to a system of iron pipes which run into a central station, where the air-pump is placed which pumps all the matter into a reservoir. The collection and sale of this matter does not usually cover the cost of the labor. The reports on this system are conflicting, and yet the majority of them speak in its favor."

Mr. C. Norman Bazalgette, in a late paper to the London Institution of Civil Engineer, says of this system from the experience gained at Leyden, Amsterdam and Dodrecht, that "it was supplementary to, and not substitutive of, a water carriage system, extremely costly, and its mechanism was extremely complicated and liable to get out of order. The accumulation of sewage residium in the central reservoir, and its subsequent decanting into barrels, were opera-

tions which could not fail to be objectionable and offensive. In conclusion, the system—though it might have a partial province in the tide-locked cities of the Hague, where no system of sewerage was available—should never be imported into an English town."

It would seem that there would be considerable difficulty experienced in the case of repairs to the pipes being needed.

THE ROCHEDALE PAIL SYSTEM.*

This consists simply in half-barrels or pails being placed under the seats of the closed privy to receive the fecal discharges; the pails being removed about once a week, after putting on a hermetically tight cover, empty disinfected pails taking their place. The matter is carried out of the town at night, and may be spread on old fields, a slight covering of dry earth being used to keep down the smell, or the matter may be sold for manure. It is well to add dry earth, ashes or charcoal every day, to the pails in use, and moreover to ventilate the privy.

This system is an excellent one for most of our towns and small cities. Having to carry the pails through the house or yard to the street is an objection. It is now being tried on a large scale in New Orleans, where the water system cannot be readily used.

All of our cities and towns can introduce this system with such a small outlay of capital, that it would seem to be the one just now to be most highly recommended.

The corporation should bear the expenses of the transportation of the excrementitious matter, as well as of other refuse and filth found in all towns, due to various causes.

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*See Appendix II, page 79.

THE DRY EARTH SYSTEM.

The great advantages offered by the "dry earth closet" is well known, and its admirable adaptability to the sick room. The system proposed is founded on this, and consists in the same pails used in the preceding system, placed in *closed privies, on firm and dry plank or concrete foundation.** The only difference is, that in this system greater care is used in spreading charcoal or dry earth over the night soil, so as to burn it up as quickly as possible, and that the pails are emptied in a tight vault on the premises, a little earth being thrown on top of the emptied mass, to keep down odor and continue the work of exodation to completion.

There appeared an excellent article on "Village Sanitary Work" in *Scribner's* for June, 1877, by George E. Waring, Jr. The writer says: "In the autumn of 1876, I had brought to my house, where only earth closets are used, two small cart loads of garden earth, dried and sifted. This was used repeatedly in the closets, and when an increased quantity was required, additions were made of sifted anthracite ashes. The amount of material now on hand is about two tons, which is ample to furnish a supply of dry and decomposed material whenever it becomes necessary to fill the reservoirs of the closets. The accumulation under the seats is discharged through valves into brick vaults in the cellar. When these vaults become filled—about three times in a year—their contents, which are all thoroughly decomposed, are piled up in a dry and ventilated place, with a slight covering of fresh earth to keep down any odor that might arise. After a sufficient interval these heaps are ready for further use, there being no trace in any portion of foreign matter or any appearance or odor differing from that of an unused mixture of earth and ashes. In this way the material

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See Appendix II, pages 77, and 78.

has been used over and over again, at least ten times, and there is no indication to the sense of any change in its condition."

The same earth can be used over and over again, thus doing away with what was once urged as the principle objection to the earth closet system—the continual removal of large bodies of earth.

A chemical analysis showed that there was no more organic matter in the used earth than in fresh earth, thus proving that in this case 800 pounds of nitrogen, etc., had gone back to the air in a harmless state, the solid organic matter being estimated at 800 pounds, of which some 230 was nitrogen.

The powerful disinfecting properties of *charcoal* are well known. When there is odor about a dead body, there is nothing better than carbon in some of its forms to destroy it. The smoke from burning tar, coffee, dried apples, etc., have all been successfully tried.

A covering of charcoal will preserve tainted flesh of any kind; the dog instinctively acts upon this principle when he buries a bone in the earth to make a repast upon some days or weeks afterwards. In all these cases it is not the charcoal or earth, but the oxygen contained in its pores that destroys the odors and burns up the substance.

As Mr. Waring says, "earth is not to be regarded as a vehicle for the inoffensive removal beyond the limits of the town of what has hitherto been its most troublesome product, but as a medium for bringing together the offensive ingredients of this product and the world's great scavenger, oxygen. This oxygen does its work of liberating the organic elements so well that, according to Professor Vœlcker, "the use of the same earth four or five times over, although perfectly successful in accomplishing the chief purpose of deodorization, fails to add to it a sufficient amount of fertilizing matter to make it an available commercial manure."

This agrees with the analysis previously mentioned. If the earth does its work thoroughly, the manure is lost, for, in truth, *this is the object to be accomplished;* to drive the organic elements back again, uncombined, or at least in harmless combinations, to the air; and this the condensed oxygen accomplishes.

One advantage of the system is that the privy or "commode," may be attached to the house; in fact the best earth closets may be kept in the chamber, without any other odor being perceived than that of the earth used, which should be *fine, dry* and *sifted.*

This dry earth system is familiar to soldiers of the late war, the sinks used by them receiving daily a slight covering of the very earth thrown out in their construction. This effectually prevented deleterious effects; and in exact accordance with the theory and facts previously adduced, the organic matter was so soon dissipated—when the system was carried out faithfully—that the earth was not worth removal as manure. This fact I know from experience; and it agrees with all other experiments and analyses referring to this point. When the earth covering is too slight, or it is neglected at times, the result will be more manure but diminished healthfulness. There can be no hesitation in the choice.

Where the dwelling place contains a garden, the used earth may be put on it, for it is quite probable that even when most, or all of the organic matter, has been driven off, that the chemical changes effected may have liberated potash or soda, etc., in the original soil, thus rendering it more valuable than before to plants.

It may be interesting to know that there is biblical sanction for this method; the Israelites being required to carry out the system whenever they went outside of the camp to ease themselves. (Deut., xxiii: 13.)

It is admitted that this system does not admit of the same public control as the preceding; but it may be made emi-

nently serviceable by those who desire it. It is especially applicable to country houses and the smaller villages.

I know of this system being carried out and satisfying the daily wants of from 70 to 100 persons—the room being almost entirely free from odor at all times. If sulphate of lime is added, it fixes the ammonia that would otherwise be driven off, and thus renders the product of some use as a fertilizer.

When epidemics prevail, then in addition to usual methods of sewage disposal, *disinfectants* should be used, as to which see another paper issued by the Board of Health on the subject.

CONCLUSIONS.

In taking a retrospective glance at what has preceded, we cannot but be impressed with the beneficence of those laws that tend, in one eternal round, to the purification of what man has made unclean. Foul sewage is thrown into a crystal stream, whose hitherto transparent waters now blush at the pollution. She invokes the aid of the ever constant winds and of the animal and vegetable life she bears in her bosom. They respond, and, in time, she is once more pure and undefiled. The pure water falls from clouds, cleanses our soil and passes into the earth, *foul*, to again issue in wells or springs, generally free from the taint of man's works.

Mother earth condenses gases that oxidize and liberate noxious, waste elements in harmless combinations. We breathe into the air a hurtful gas; but the winds and the rains bear it from us, or the vegetation reaches out its leaves, with their million little mouths, to absorb it and give us in exchange the life giving oxygen.

Is it asking too much, should Nature call sometimes for man's assistance to expedite results, in order that he may add to his days and happiness? If not, then ponder well

on the means that have been proposed to assist nature in her work of purification, and act on them.

It is not intended that the foregoing brief summary of "means" is complete. It was not intended to be, though fundamental general principles, proper to be known at present, it is hoped have been stated clearly and fairly.

Burton says that most men make books like apothecaries make medicine, by pouring from one bottle into another. This one belongs to that class—successful experience has been inculcated rather than novel theories. The solutions used have been standard ones—often huge bottles have been poured from, even the crude materials of the *still* have been obtained and digested before using. Most of the elixirs mixed beautifully, forming clear solutions; others did not, and had to be specially treated to remove the antagonistic elements, whilst others as my "germ" bottle would not pour at all scarcely, the fluid being dark and viscid.

The object of such papers as this is to advise the public, who cannot be thinking all the time about sanitary matters, with regard to efficient means of protection against sickness, and especially against epidemics. The county boards of health are looked to as the authorized agents in introducing more effective sanitary measures. But it is well known that such organizations cannot go far ahead of public opinion. We need the aid of the press, the great educators of public opinion, to assist in the good fight for health.

Let some of the systems for the disposal of sewage matters be faithfully carried out simultaneously with a proper attention to ventilation, drainage, water supply, and the general cleanliness of streets and yards, and it is believed that the death rate will be lowered and that epidemics will be almost unknown.

Let every open privy and cess-pool be abolished with their pestilential odors; it follows that the source of contamination of the wells will be gone, and that zymotic diseases will have their usual channels of attack effectually cut off.

Let us, then, advance towards that higher civilization which demands pure air and wholesome water, not simply as a luxury to be enjoyed only on the cool mountain's sides, but as a necessity, to be enforced in city and village by stringent laws and requirements.

APPENDIX I.

The following table may prove a convenience to those who use cisterns. It gives the capacity of a cylindrical cistern, for one foot in height, and the diameters given, in U. S. liquid gallons (of 231 cubic inches each), the nearest whole number being taken:

DIAMETER. Feet.	CAPACITY. Gallons.	DIAMETER. Feet.	CAPACITY. Gallons.
5	147	15	1322
6	211	16	1504
7	288	17	1698
8	376	18	1903
9	476	19	2121
10	587	20	2350
11	711	21	2591
12	846	22	2843
13	993	23	3108
14	1151	24	3384

Multiply these tabular numbers by the height of the cistern in feet to get the capacity of a cistern corresponding to that height.

APPENDIX II.

Through the courtesy of Dr. Charles F. Folsom, of the Massachusetts Board of Health, the accompanying wood cuts are presented—they having first appeared in the Massachusetts Report of the Board of Health for 1876.

The cuts represent in order the natural drainage from open privies and sinks, into wells that are placed too near them; sections of common privies and sink hole, both polluting the soil around them; and lastly, three plans for privies based upon the dry earth system.

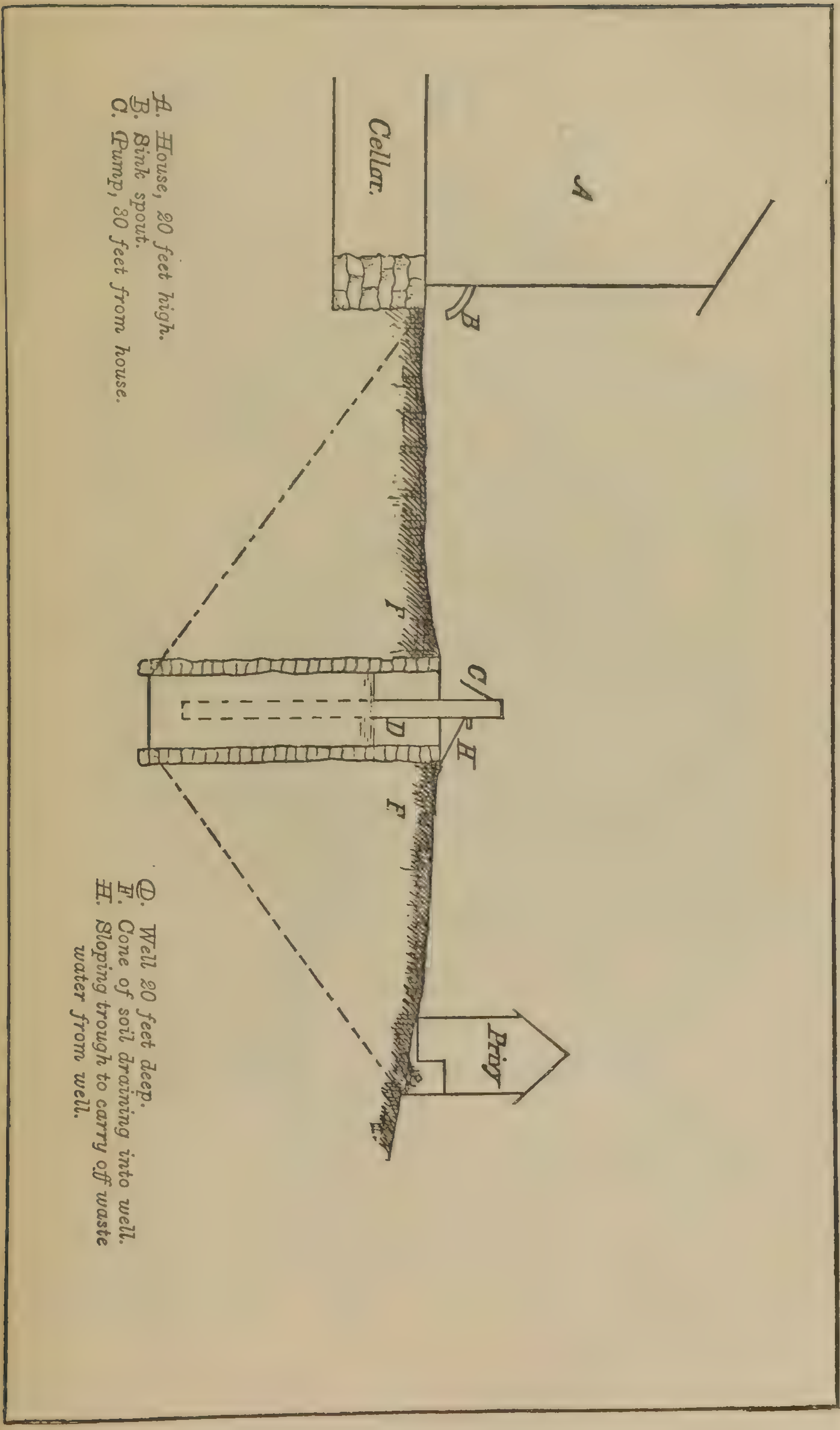
It is to be observed with respect to the latter, that the conditions are simply that the pails used be completely under cover and placed upon a dry foundation, so that no matter from the pails shall ever reach the ground below them, thereby poisoning the air with its effluvia and the wells with its drainage.

It is necessary that the earth, charcoal or ashes be kept in a dry place and under cover, the most convenient place being an apartment just to the rear of the pails, from which it can be readily shovelled into the pails *under* and not *through* the seats as when the ashes etc., are kept in the privy room proper.

An ordinary open privy can generally be transformed into one closed from the access of rain, by cutting out a space in the weather-boarding of the back, nearly as high as the top of the seats, and replacing this boarding by a door working on vertical or horizontal hinges, as shown in one of the figures. On opening this door, the half barrels or pails can be set under the seats, and every morning charcoal, etc., can be thrown over the contents so as to keep down all odor. The pails should be set upon a plank or stone foundation—at least upon a few blocks or bricks—to elevate them a few

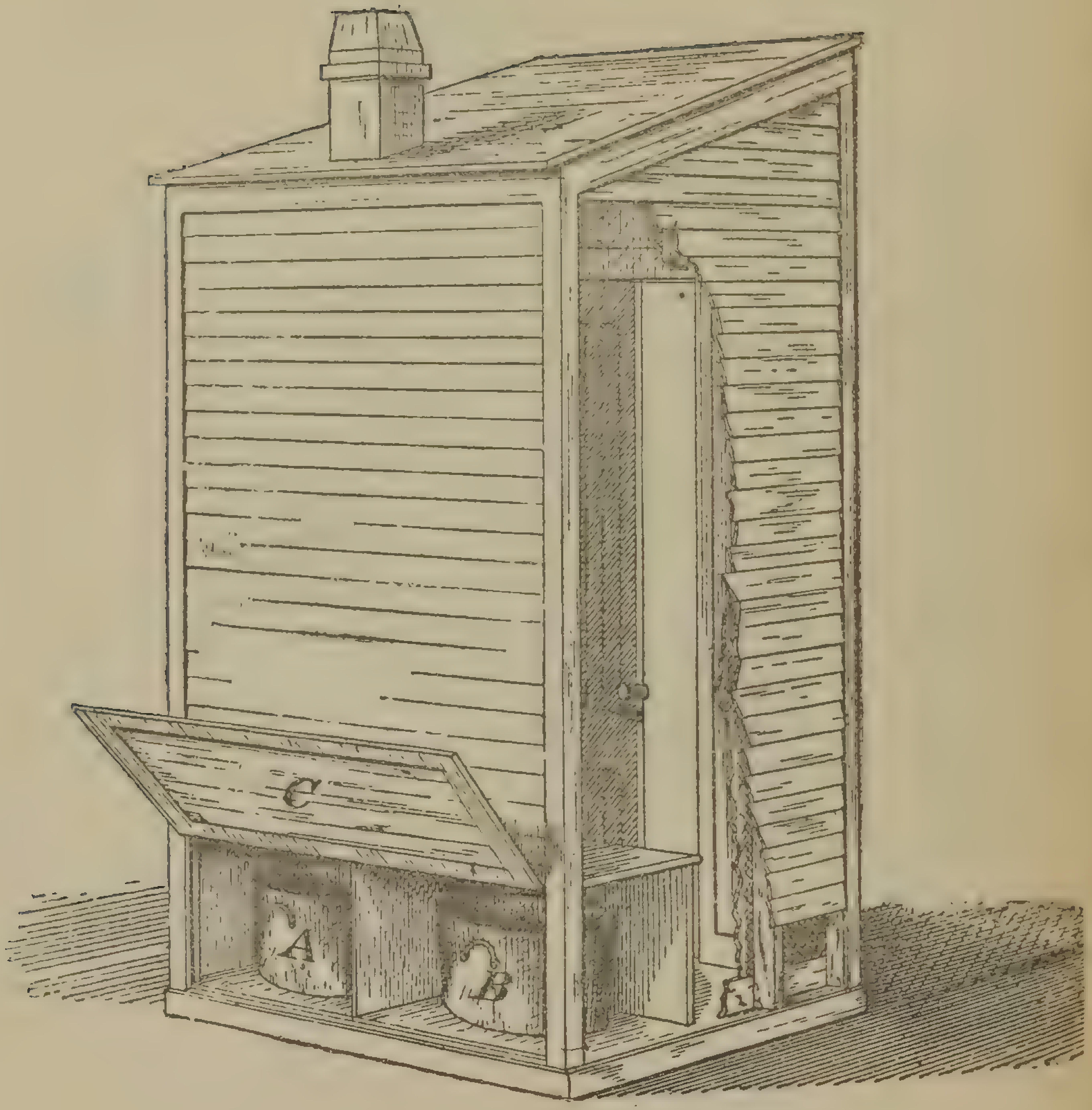
inches above the ground, so that water may not reach them. As the pails are filled they should be emptied under a shed and dry earth, etc., strewn over the contents, the action of which in destroying the organic matter has been already explained.

Where wells are at a distance, the contents of the pails might be emptied on cultivated ground for their manure, a slight covering of earth being again used to keep down any odor that might arise.


A
Cellar.
B
C
D
F
F
H
Privy
A. House, 20 feet high.
B. Sink spout.
C. Pump, 30 feet from house.
D. Well 20 feet deep.
F. Cone of soil draining into well.
H. Sloping trough to carry off waste
water from well.


Common Sink-hole and spout
B. wooden spout
C. sink hole in ground
D leaching from same.
B
Side of house.
F
S
A
Section of Privy with pit, and board sides
F
S
A
Section of common style of country privy on a slope
F, floor.
S, seat.
A excrement.
B leaching of fluids into soil.


Manchester Corporation.
Dry ash closet. Section.
Yard
Screens to separate cinders from ash and direct the latter onto the excrement.


C
A
B

Rochdale Corporation
Pattern Pail closet.

A. excrement pail.
B. ash tub.
C. seat cover (raised)
D iron collar below seat, reaching slightly into pail when cover is down.
F. hinged upright of seat.
G. door admitting from outside to excrement pail.

APPENDIX III.

The following lucid description of the ventilation of the State Lunatic Asylum of New York, located at Utica, N. Y., is taken, by permission of its author, Dr. John P. Gray, from the "Thirty-sixth Annual Report of the Managers of the State Lunatic Asylum."

It is prefaced by a short extract from the report:

"The managers consider the method of heating and ventilation of the institution to be the safest, most economical, and best. Information is frequently sought as to the system adopted. Recently an application made through the State Department by the British government for a detailed statement concerning the appliances and method, was referred to Dr. Gray, the superintendent of this institution, who made a report which was submitted to this board before transmission. The managers deem it such a clear and succinct statement of the method adopted, that they embody it as a document worthy of permanent record for use and reference.

Mode of Ventilating and Heating.

1. The mode of ventilation adopted is that of forcing air into the building by the use of two centrifugal fans, a drawing and description of which accompany this communication.

2. The air is delivered from the fans to all parts of the building.

3. First: Into the large channel or basement air duct, or air plenum, which is continuous under the whole building.

4. Second: From this air duct or air plenum, the air passes by flues into the various wards and rooms to be supplied. Each flue is independent; that is, it has an exit at but one point. These flues open into the wards or rooms to be supplied at a point above the level of the top of the windows and doors, so that no air movement caused by opening a window or door will disturb the current of the incoming air. The air is thus distributed uniformly through every part of the building.

5. From the corridors and rooms flues are constructed, starting just above the base-board, each flue passing independently into the attic air chamber. Over part of the building there is ridge ventilation. Over other parts of the building the exit is through ventilators fixed at regular distances.

6. Each fan delivers at each revolution 1,000 cubic feet of air. They can be driven to supply almost any desired quantity. They are here driven night and day, and supply 5,000,000 cubic feet of air per hour, which is a little over 100 cubic feet per minute to each occupant of the house night and day.

7. The main air duct or plenum is large enough to contain any quantity of air desired, without the need of a rapid current. The area of the flues leading from this duct to the wards and rooms is equal to forty-two inches for each occupant. The exit flues from the wards and rooms to the attic chamber is equal to sixty-four inches for each occupant. The exit area through the ridge ventilation and ventilators equals seventy inches for each occupant.

8. In every single sleeping room there is a flue for the exit of air of sixty-four inches area. In associate sleeping rooms the area of the several flues is equal to sixty-four inches for each occupant. The flues for the supply of air open on the corridors at the height already stated. The sleeping rooms receive the air from the corridors at or near the floor.

In some of the wards there is no threshold under the door, and the doors are shortened at the bottom to allow a space between them and the floor of sixty-four inches area. In some the air enters the sleeping rooms through a register in the bottom rail of the door. In the associate sleeping rooms, where sufficient air could not thus be obtained for several patients, openings are made through the walls at points near the floor. In a few of the rooms for the feeble the flues for the supply of air open into the rooms.

9. This mode secures the most abundant supply of fresh air. It secures what ventilation means practically: that is, such constant *dilution* of the body of the air contained in the building by fresh air sent in as to make it for all practical purposes pure.

10. I do not use the words "fresh and foul air flues." In reality, this method secures a constant flow of pure air through the building from its entrance to its exit, and the gradual enlargement of the areas facilitates the passage and exit of the air, and compensates for the frictional resistance in passing through the building.

11. It is stated in paragraph four that the air is introduced at a height above the doors and windows. While this is undoubtedly best, it is not absolutely necessary to success in ventilation. It is proper to say that in a hospital for the insane, it is advisable to have the air enter above a point where patients would be likely to throw articles into the flues, and also to avoid the evil of patients crowding about the flues and impeding the thorough distributions of the air. In the offices of the institution, in the residence of the officers, and some of the rooms not constantly used in the hospital proper, the air is introduced just above the baseboard, and in some instances through the floor; but in all cases, no matter where the air is introduced, the exit flues should start from near the floor as already described. Where the air is thus introduced, it is important to locate the flues so as not to have them opposite windows.

12. Where the rooms are large, as in case of parlors and sitting rooms, and require two or more flues for the introduction and exit of air, it is important to distribute them so that all parts of the rooms shall be supplied uniformly.

13. Heating is combined with ventilation. The air is warmed to the degree required by being compelled to pass over cast iron radiators, through which steam is circulated, on its way from the fan to the occupied parts of the building. These radiators are placed in the main air duct or plenum, and are in separate blocks directly underneath the flues leading from this duct to the occupied parts of the building. There is a box of radiators for each set of three flues, one flue leading to each story. Each block has an independent connection with the main steam pipe, so that each block can be used separately. Each block is cased in on the sides leaving the bottom open for the free passage of air over the radiators. By this arrangement the air is warmed at the nearest point of its delivery for use, and the heat is not wasted by absorption into the walls of a large general air chamber, and the temperature of the air sent into any special part of the building can be regulated as may be desired, simply by introducing more or less steam into the individual blocks.

14. These radiators are so constructed and connected as to make what is called a "steam coil," and the blocks are so arranged and connected that steam can be turned upon one-third, two-thirds, or the whole, as the atmospheric temperature may require. Of course, there is no impediment to the passage of the air through these blocks for summer ventilation when heat is not needed, as the space between them is sufficient for the passage of the largest volume of air required.

15. This large body of air entering and distributed in the manner described produces no appreciable current. It is not found necessary to raise the temperature of the air introduced higher than 100 degrees at the point of entrance

to the wards and rooms, in order to secure a general temperature of seventy degrees throughout. Thus the air is not rarified, expanded, or dried, to a degree that interferes with healthfulness and comfort.

16. This system does not require registers to control the temperature of the room by closing and unclosing them. The amount of air delivered over each radiating block is warmed to the temperature there required, and as the volume of the air delivered is uniform and constant, thorough ventilation is obtained. Registers in the wards of a hospital would be likely to be used to close off the flow of air if it was too warm, that being easier done than to give information to the engineer having control of the heating blocks. Registers are used in the offices and residences of the officers.

17. It is possible to determine the exact amount of coal necessary to raise a given amount of atmosphere one degree, and this gives the key to the necessary amount of coal to be burned in the steam boilers to raise the whole quantity of air introduced to any desired temperature. The engineer by observing the temperature of the external atmosphere, and knowing the volume of air delivered, can, with sufficient accuracy, supply the necessary amount of heat.

18. To illustrate: The cubic capacity of the wards and rooms of this asylum is, in round numbers, about 5,000,000 feet. Five million cubic feet of air sent in by the fans per hour night and day. Twelve pounds of coal will raise this atmosphere one degree per hour. At this writing the average outside temperature for the past twenty-four hours has been ten degrees below zero. The temperature of the wards has been maintained at from seventy to seventy-two, and we have burned 8 tons and 1,280 pounds of coal, an average of 720 pounds per hour; the actual number of occupants 722.

DESCRIPTION OF FAN.

The fan and its support are of iron, the casing of wood;

the rotary or operating part of the fan consists of a shaft with eight radial arms set back on a curve at the extremities of which are fastened iron wind boards, three feet wide and five feet long, in the direction of the axis; the extremities of the wind boards are six feet from the center and consequently describe a circle of twelve feet diamter. The shaft extends beyond the casing and rests on pulley blocks, and on the driving side it is lengthened six feet to receive the driving pulley and remove all obstruction to the easy entrance of air to the fans; the motion is imparted by a belt passing over the pulley, four feet in diameter, with ten-inch face, on the end of the shaft, the arms and boards revolve within the wooden casing, the circumference of which instead of being concentric with the shaft, describes a curve of increasing diameter and forms outside the wind boards a channel of constantly enlarging capacity towards the point of delivery. The casing is therefore scroll-shaped, this space being six inches in front and enlarging to three feet at the bottom. The height of the casing from the floor is eighteen feet. The cross-sectional area is equal at the point of delivery to forty-two square feet. The opening in each side of the fan-casing, for the inlet of air, is six feet in area. This whole machinery is placed in a room, the floor of which is on a level with the floor of the main air duct, and the air is admitted through a large open space, double the area of both inlets, and properly guarded.